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Vegetation Community Changes in Two National Forests in the Pineywoods, East Texas

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VEGETATION COMMUNITY CHANGES IN TWO NATIONAL FORESTS IN THE PINEYWOODS, EAST TEXAS

By

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ABSTRACT

Despite extensive research into forest succession, little research has been directed to long-term studies. The fundamental properties of succession remain unclear and further research into terrestrial vegetation and an accounting of drivers in specific ecosystem types is required. This study addresses change in plant communities from five ecosystem types in two east Texas National Forests over a 20-year period. An analysis of 30 sample stands yields results due to various ecosystem drivers of vegetation change and uncovers plant community responses in multiple ecosystem types over this period. This research provided three key results: 1) that vegetation composition change occurs more dramatically in longleaf pine, dry-mesic and mesic ecosystem types; 2) that vegetation composition change can vary within different organizational levels of an ecosystem; and, 3) that long-term studies of these areas will emphasize species-time-area relationships that can effectively link vegetation composition/dynamics to disturbance drivers. This study is part of a growing body of research on long-term studies relating to forest succession. This project will serve as a benchmark that will contribute to future research on similar topics.

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CHAPTER 1 - INTRODUCTION

There is a long history of observing terrestrial vegetation characteristics in the Pineywoods of east Texas (Tharp, 1926; Gould 1975; Diggs, et al., 1999, 2006). A number of vegetation studies have been conducted describing plant communities in the Angelina, Davy Crockett, Sabine, and Sam Houston National Forests areas (Van Kley and Hine, 1998; Van Kley, 1999a; Van Kley, 1999b). Accordingly, existing patterns of the natural vegetation in east Texas are reasonably well documented. Nevertheless, a quantitative examination of vegetation change within individual forests stands in this area has not been undertaken to date. There exists a need to determine changes of composition and distribution of vegetation in these areas as it directly impacts socio-economic and demographic concerns (Outcalt, 1997; Connor and Craig, 1989; Comiskey and Dallmeier, 1998). Van Kley, et al. (2007, 2009) remains the latest primary work describing vegetation in east Texas. His work was based on the study of over 500 sample sites within east Texas and west Louisiana in the mid-1900s. With this study, I have characterized vegetation change in 30 stands over an approximately 20-year period (1994-2016) in two east Texas national forests. This work is almost entirely holistic but delves into some reductionist principles. More specifically, each stand has been characterized into defined ecosystem types and each ecosystem type is further divided by stratum. Vegetation community composition and attributes such as diversity, evenness, species richness and turnover rates were examined using parametric and nonparametric statistical methods to establish observable and measurable patterns of change in vegetation communities. An attempt to interpret vegetation patterns was also considered based on local disturbance factors with respect to each ecotype system under investigation. However, hydrologic patterns, seedling distribution, plant traits and other factors that can result in vegetation change within these study areas require further investigation.

CHAPTER 2 - STUDY AREA

i. History and Land Use

The indigenous peoples of east Texas (e.g. Caddoan) practiced cultural and agricultural techniques that included the regular burning and the cultivation of forests in the area well before European settlement (Mann, 2005). Accordingly, the “natural” forests of the area were subject to human management long before the southern states experienced European settlement in the early 1700s (Frost, 1993). It is well documented that a major disturbance to the forests of east Texas occurred in the early 1900s due to commercial exploitation (logging, plantations, agriculture, etc.). Since that time these forests have undergone forest management practices for conservation, preservation or aesthetic reasons which has resulted in less than three percent of the primary forests remaining today (McWhorter, 2005). The current forests of east Texas have, therefore, been altered from their natural state and even older stands are now best described as being in late successional recovery from these earlier disturbance events.

ii. Geography and Climate

The West Gulf Coastal Plain comprises a gently downward sloping and a geologically progressively younger landscape that follows a south-easterly trend towards the Gulf of Mexico. The area broadly encompasses approximately 19 ecological landtype associations (Van Kley, et al., 2007) and soils that vary significantly but can be generally described as ranging from fine sandy loams to clays on the uplands and heavy alluvial bottomland clays having shrink-swell properties. The ecological subregion for this study is the Pineywoods Transition Subsection of the Outer Coastal Plain. This region is positioned between the Southeastern Mixed Forest Subregion to the Louisiana border. Mean monthly temperatures in the area are strongly seasonal and averages between 15.6°C (60°F) to 34°C (94°F) on an annual basis (Diggs, et al., 2006). East Texas has a high affinity to tornadoes, thunderstorms and lightening-started fires, which are all well-known factors driving vegetation dynamics (Kapfer, et al., 2011).

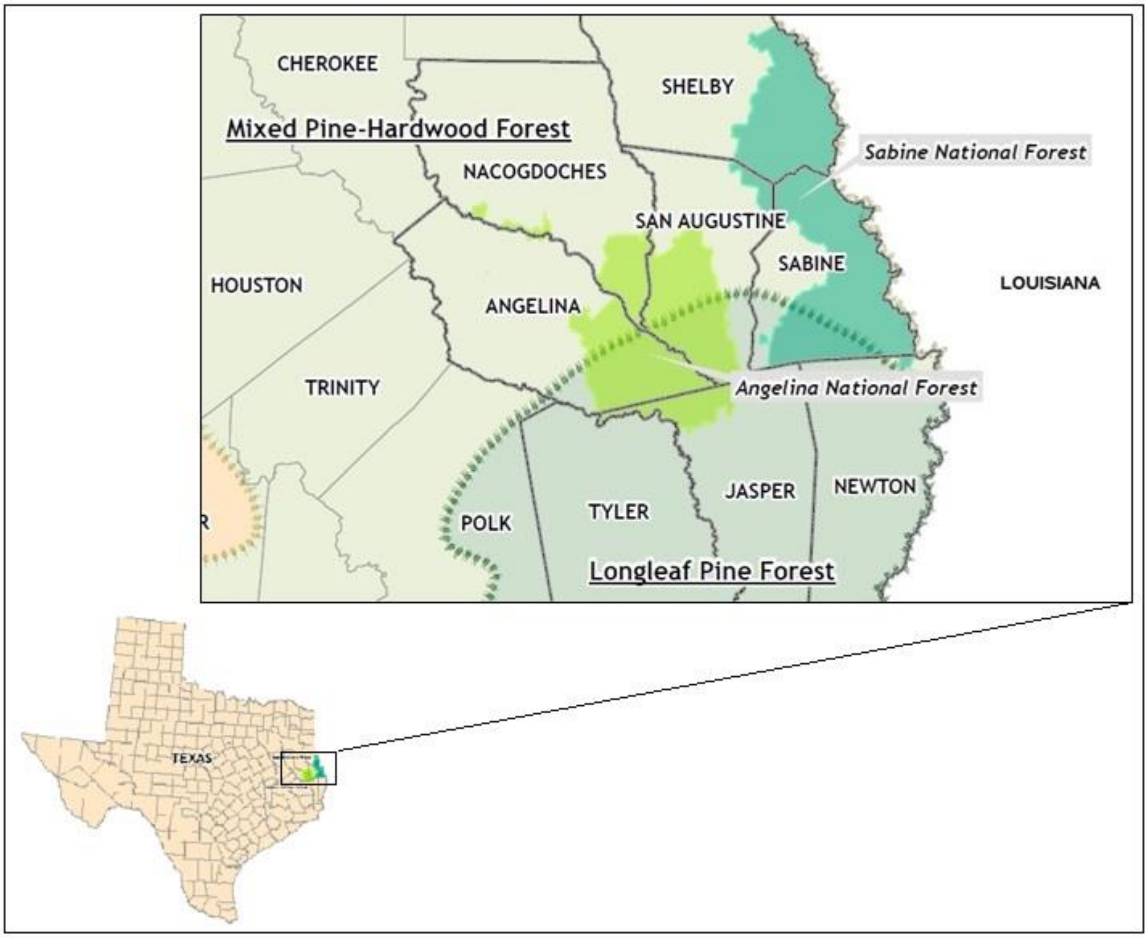

Figure 1 – A map of the study area of the 30 upland forest stands in the Angelina and Sabine National Forests, Texas, USA, sampled in 1994/95 and resampled in 2016.

All 30 stands of this study were selected from plots previously sampled in 1994 or 1995 and allocated permanent markers in the Angelina National Forest and the Sabine National Forest of east Texas (Figure 1). The Angelina National Forest covers 61,989 ha (153,179-acres) over 4 counties (Angelina, Nacogdoches, San Augustine and Jasper). Approximately 49 percent of this forest is to the northeast and 51 percent is to the southwest of Sam Rayburn Reservoir (Connor and Craig, 1989; Figure 2). The Sabine National Forest is located approximately 15 km (9.3 mi) east of the Angelina National Forest on the western slope of the Sabine River watershed and comprises 65,015 ha (160,656-acres) covering five counties including the Sabine, San Augustine, Shelby, Jasper and Newton counties (Figure 3). A summary of the stands and their selection date, counties and GPS coordinates (Projection system: World Geodetic System 1984 - WGS84) for the first and last subplot of each stand are identified in Table 1.

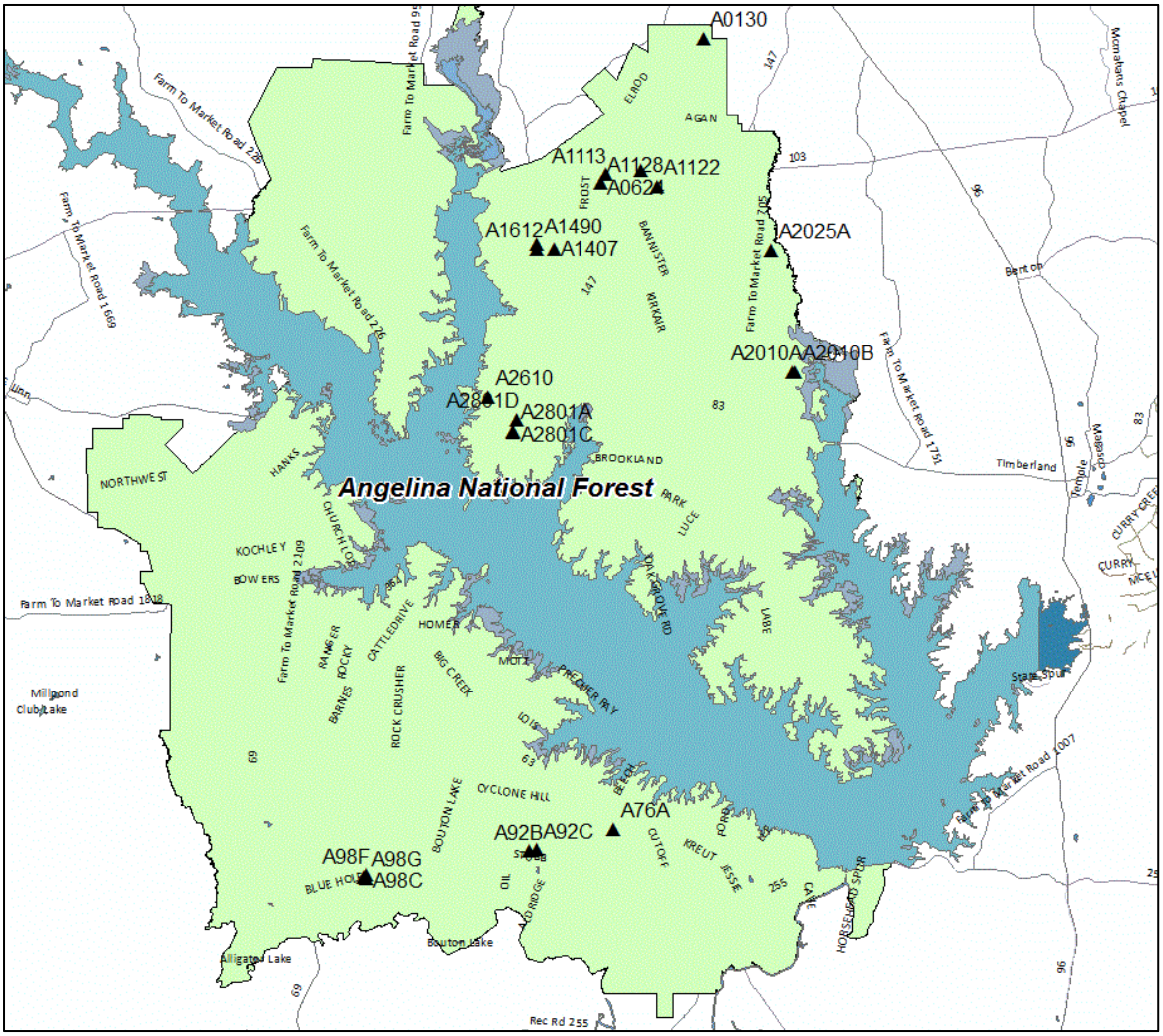

Figure 2 - A map of the Angelina National Forest, Texas, USA, indicating 21 of the 30 upland forest sites sampled in 1994/95 and resampled in 2016.

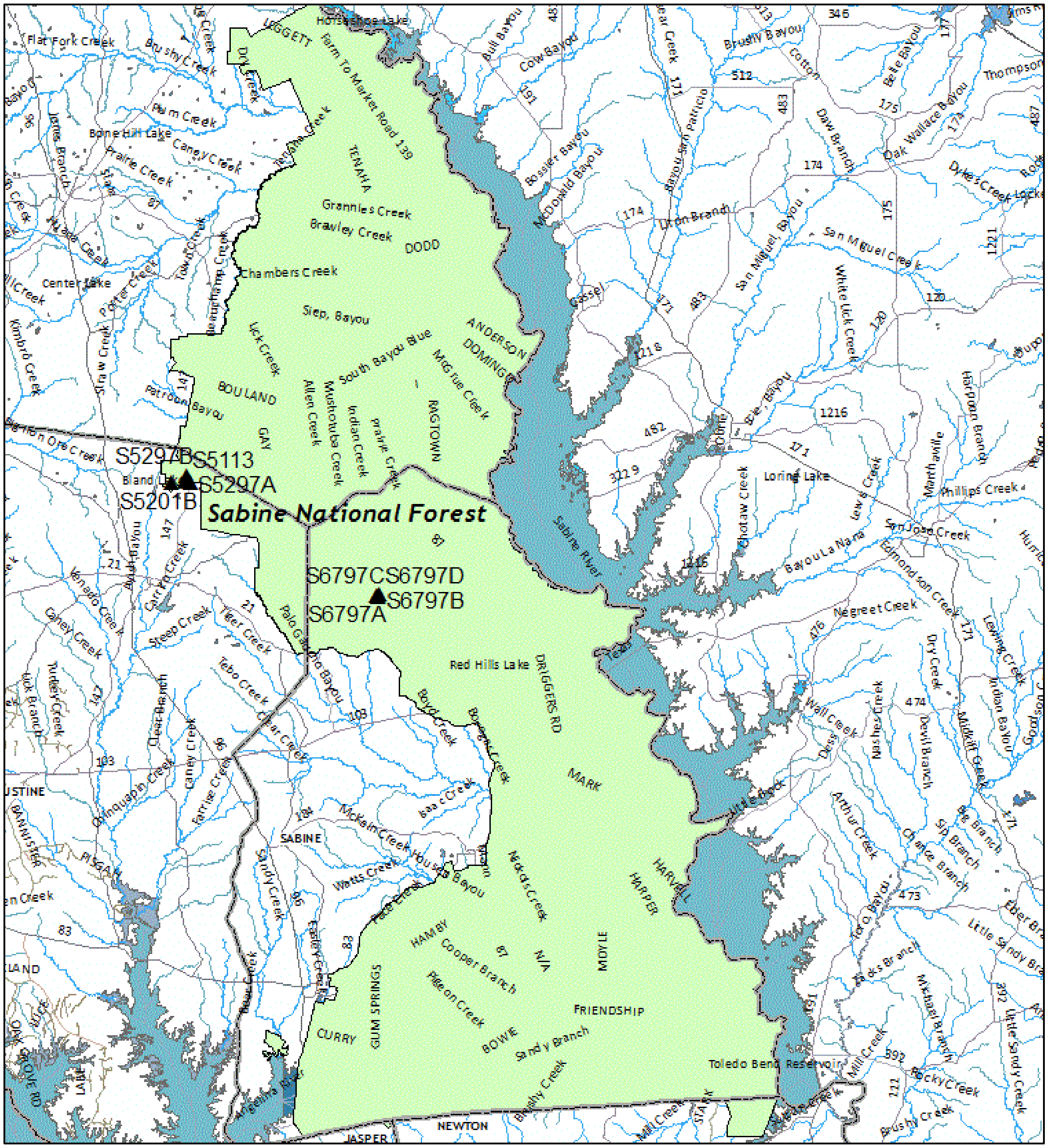

Figure 3 - A map of the Sabine National Forest, Texas, USA, indicating 9 of the 30 upland forest sites sampled in 1994/95 and resampled in 2016.

Table 1 – A summary of the 30 upland forest stands in the Angelina and Sabine National Forests, Texas, USA, sampled in 1994/95 and resampled in 2016, with their respective counties and GPS Coordinates (DMS) for the first and fourth subplots.

		GPS - 2016 - SUBPLOTS 1 AND 4 (DMS)			
STAND	**COUNTY**	**LAT (N)**	**LONG (W)**	**LAT (N)**	**LONG (W)**
A76A*	Angelina	31°04'50.7"	-94°14'03.0"	31°04'49.6"	-94°14'02.9"
A92B*	San Augustine	31°04'11.5"	-94°16'51.9"	31°04'09.7"	-94°16'52.6"
A92C*	San Augustine	31°04'13.7"	-94°16'35.9"	31°04'15.3"	-94°16'35.8"
A98C*	Angelina	31°03'22.9"	-94°22'15.7"	31°03'20.2"	-94°22'16.8"
A98F*	Angelina	31°03'27.8"	-94°22'15.7"	31°03'25.5"	-94°22'16.1"
A98G*	Angelina	31°03'23.7"	-94°22'20.6"	31°03'22.1"	-94°22'22.0"
A0130	San Augustine	31°27'27.8"	-94°11'22.0"	31°27'28.6"	-94°11'20.7"
A0624	San Augustine	31°23'41.7"	-94°13'23.6"	31°23'40.5"	-94°13'25.8"
A1113	San Augustine	31°23'33.4"	-94°14'34.9"	31°23'33.4"	-94°14'32.6"
A1122	San Augustine	31°23'14.3"	-94°12'50.1"	31°23'14.9"	-94°12'51.5"
A1128	San Augustine	31°23'18.4"	-94°14'44.6"	31°23'18.1"	-94°14'42.6"
A1407	Angelina	31°21'23.0"	-94°16'15.7"	31°21'23.3"	-94°16'18.8"
A1490	San Augustine	31°21'31.7"	-94°16'49.7"	31°21'31.4"	-94°16'49.0"
A1612	Angelina	31°21'24.1"	-94°16'49.4"	31°21'23.0"	-94°16'49.1"
A2010A	San Augustine	31°17'58.3"	-94°08'16.2"	31°17'58.2"	-94°08'14.1"
A2010B	San Augustine	31°17'58.3"	-94°08'12.2"	31°17'59.3"	-94°08'10.6"
A2025A	Sabine	31°21'26.1"	-94°09'02.2"	31°21'25.3"	-94°09'00.7"
A2610	San Augustine	31°17'09.5"	-94°18'24.0"	31°17'09.1"	-94°18'21.4"
A2801A	Sabine	31°16'12.0"	-94°17'33.8"	31°16'12.2"	-94°17'35.1"
A2801C	San Augustine	31°16'09.8"	-94°17'32.1"	31°16'10.8"	-94°17'30.8"
A2801D	San Augustine	31°16'31.2"	-94°17'25.0"	31°16'30.6"	-94°17'22.6"
S5113*	San Augustine	31°35'55.9"	-94°05'01.5"	31°35'54.2"	-94°05'02.4"
S5201A*	San Augustine	31°35'52.1"	-94°05'41.9"	31°35'54.0"	-94°04'42.8"
S5201B*	San Augustine	31°35'51.7"	-94°04'46.8"	31°35'53.0"	-94°04'45.8"
S5297A*	San Augustine	31°35'54.5"	-94°04'52.1"	31°35'55.9"	-94°04'52.9"
S5297B*	Angelina	31°36'06.7"	-94°04'59.7"	31°36'06.2"	-94°04'58.0"
S6797A*	Sabine	31°31'15.8"	-93°55'35.6"	31°31'15.1"	-94°55'37.8"
S6797B*	Sabine	31°31'12.8"	-93°55'39.4"	31°31'12.3"	-94°55'37.6"
S6797C*	San Augustine	31°31'10.9"	-93°55'39.4"	31°31'09.5"	-94°55'39.5"
S6797D*	Sabine	31°31'12.4"	-93°55'41.3"	31°31'10.8"	-94°55'41.0"

Stands sampled in 1995 are indicated with an asterix, all remaining stands were sampled in 1994.

iii. Research Objectives

The objective of this research was to characterize vegetation changes that occurred over approximately 20 years in 30 forested stands, encompassing several ecosystem types, that were originally sampled in the spring/summer of 1994 and 1995 and resampled in the summer of 2016. The aim of this study was to compare and contrast temporally paired ecosystem types by strata using non-parametric techniques (i.e., TWINSPAN and ordination) to determine if any vegetation change had occurred. TWINSPAN is a divisive clustering method that arranges similar samples close to one another. This method is typically a preliminary step that groups important species in such a way that the final dendogram output may then be used to aid in identifying species patterns. Ordination techniques are useful in that they reduce many datapoints typically scattered in multiple dimensions into just a few dimensions, so that they can be visualized and interpreted. Another aim of this study was to use indices, such as Shannon and Pielou's evenness, and species richness and turnover rates of the sampled vegetation to compare, using parametric methods (i.e., two-sample t-tests and ANOVAs), whether these vegetation communities had changed significantly within the past 20 years, and if these changes occurred only in specific ecosystem types and/or within one or more strata. It was a further objective of this study to elucidate possible disturbance factors that may have contributed to any changes found within or between the ecosystem types. In addition, no long-term successional studies have been undertaken in the

Pineywoods ecological subregion to date to the best of the author's knowledge. Accordingly, the overarching objective of this thesis is to serve as a benchmark for an ongoing long-term study to better understand the dynamics of vegetation change in east Texas.

CHAPTER 3 - LITERATURE REVIEW

i. Succession

Vegetation change in a forested community was first termed "succession" by French naturalist Dureau de la Malle (Dureau de la Malle, 1825). Since that time succession has become a basic theory of ecology but remains to this day a controversial one. Agreement on this basic theory arises when describing primary and secondary succession. Primary succession occurs when a completely denuded area begins to be populated by plant organisms. Secondary succession is when a major disturbance results in the re-establishment of the area by the previous vegetation or through recruitment of new plant organisms (Royo and Carson, 2006). The controversy arises when attempting to describe succession in terms of scale and time (Finegan, 1984). For example, a small area may fluctuate dramatically during a short period of time, but if that area or the time period is expanded there may be less observable change in vegetation patterns. There is a relatively long history of competing succession models that range from holistic viewpoints where communities have sharply bounded areas and a reciprocal interactiveness (Clements, 1916) to the more reductionist theories where communities are less bounded, less interactive and more subject to chance occurrence (Gleason, 1926). Succession has also been explored with respect to both broad (high order) and restricted (low order) mechanisms (e.g. competition, facilitation, tolerance, autogenic and/or allogenic factors, etc.) in an effort to explain successional processes and models. However, there is presently no consensus in the ecological literature directly explaining observed vegetation changes in plant communities (Austin, 2005). Moreover, there remains some argument that the mechanisms currently in use are no longer of importance to ecological investigations (Davis, et al., 1981; Bruno, 2003). Regardless, there is overwhelming agreement that continuing to study and attempt to describe succession is important, with the need to both understand short term vegetation change as well as to better predict outcomes of vegetation manipulation and management as it has an enormous ability to contribute to the scientific community and to society (Finegan, 1984; Bakker, et al., 1996; Shurin, 2007; Li, et al., 2017). This thesis does not attempt to extrapolate patterns of existing theoretical models or mechanisms but does qualitatively and quantitatively examine temporal forest dynamics in the sample areas under study to further understand successional patterns in east Texas. In this respect, the term "succession", as used herein, relates specifically to secondary succession.

ii. Disturbance

Regions with high disturbance are useful for understanding succession since forest disturbance can affect structural and compositional dynamics of forested communities (Dale, et al., 1986). During the 20-year period of this study three major disturbance events occurred in east Texas. The first major event occurred in 2005 (September 22-26th) when Hurricane Rita impacted portions of southeast Texas. The winds from Hurricane Rita reached 175mph and maintained tropical storm strength as it entered Louisiana (Roth, 2010). The second major event occurred on September 13, 2008 when Hurricane Ike, a category 2 storm, entered Texas from the Gulf of Mexico. Maximum winds were recorded at 110mph and affected over thirty-four Texas counties, including the areas of the current study (Zane, et al., 2011). Damage to forest vegetation was highly variable and dependent on many elements such as tree size, wind resistance and coverage from natural windbreaks such as hillsides and dense shrub or tree areas (Everham and Brokaw, 1996). Accordingly, wind disturbance is an important consideration in successional studies given the possible effects to forest dynamics (Allen, et al., 2012).

The third major event in east Texas relates to the severe Texas drought of 2011. In a briefing packet to the Texas legislature, east Texas was described in 2011 as having widespread vegetation mortality. Dry and windy conditions also promoted intense forest fire burns in the area during the early Fall (Nielsen-Gammon, J. W., 2011). Therefore, important environmental repercussions from extreme dry conditions may impact plant communities (Marks and Harcombe, 1981).

On a smaller scale, large clearance episodes from fire has been correlated with an overall increase in herbaceous species diversity at the expense of some arboreal (Kazanis and Arianoutsou, 2004; Palmquist, et al., 2015). The United States Forest Service currently maintains a forest management practice in the Sabine and Angelina National Forests of prescribed random and periodic burns for conservation purposes, particularly for the enhancement of longleaf pine (*Pinus palustris P. Mill.*). Notably, changes in species richness have been linked to changes in other abiotic and biotic factors (Marks and Harcombe, 1981; Olofsson, et al., 2013).

Feral hog populations have also increased considerably in east Texas since their first introduction to the United States by early European settlers. Although initially a relatively small population of feral hogs were introduced, feral hog populations have since increased to concerning proportions in recent decades. The hogs obtain much of their diet by rooting in the soil, breaking the surface vegetation layer, followed by excavation (Wirthner, et al., 2012). The increasing hog population is paralleled by the growing concern that the hogs are now altering or irreplacably destroying the natural herbaceous vegetation of east Texas (Chavarria, et al., 2007). Accordingly, the influence of hog activity on vegetation patterns must be considered in the determination of factors driving change in the landscape of east Texas.

iii. Biodiversity

Biodiversity is a term used to describe variability among species within and/or between the various organizational levels of an ecosystem. It comprises quantitative measures and indices for comparing biological entities using valid statistical treatments (Heip, et al., 1998). Species richness is the most basic measure of diversity and reflects a count of the number of species present in a community. The Shannon Index (H'), also known as the Shannon-Weiner Index and sometimes erroneously referred to as the Shannon-Weaver function, is an expression of the relationship between the number of species and the number of individuals in the community (Spellerberg and Fedor, 2003). Pielou's evenness (Pielou, 1966) is an indice where J' is the ratio between Shannon's entropy and the maximum H' and is a measure of species equity within the dataset. Species turnover is also considered and refers to the local extinction and replacement of species over an established time period (Panitsa, et al., 2008; Chepinoga, et al., 2012). An accounting of biodiversity within a plant community is the first step in achieving an understanding of the contribution diversity may have to the ecosystem under study and provides the resources necessary to attempt to determine how to maintain diversity.

iv. Long-term Studies

There is a considerable lack of long-term studies available to the scientific community from which to draw a fundamental understanding of succession given the short-term transitory adaptations that the community undergoes (Scharf, 2002; Palmquist, 2015). Perhaps one of the most prominent reasons for the lack of consensus in succession models is due to the fact that most attempts to describe succession rely on small amounts of data, collected in relatively small areas at discrete moments in time (Shugart, 1984). Accordingly, there has been a call for long-term studies of succession to examine different stages of change within ecosystems (Shurin, 2007; Rudolf and Rasmussun, 2013). Whether the plant community under investigation is experiencing stages of community change, or merely a resilience to conditions, will not be realised for some time. However, the only way to understand the eventual outcome is to have an adequate amount of experimental and/or field data over time to make the appropriate models (Bakker, et al., 1996; Kazanis and Arianoutsou, 2004). Public and private policy-makers will be unable to predict the outcome of present-day management practices without some understanding of the processes and stages of succession due to various disturbance factors.

CHAPTER 4 - METHODOLOGY

i. Field Design

A pool of 36 permanent stands, established between the spring and summer of 1994 and 1995 (hereinafter identified as data from “1994/95”), was surveyed in preparation for this study. These initial stands represent a dataset of over 500 stands from the four National Forests in east Texas and Louisiana’s Kisatchie National Forest that were previously used to develop a multifactor Ecological Classification System (“ECS”) (Van Kley and Turner, 2009). Using previously recorded GPS points for the first subplot, hand drawn landmark maps of the areas made during the original data collection and a metal detector, the four original subplot markers were located in each stand and new GPS points for the fourth subplot markers were recorded. A new GPS point was also recorded for the first subplot if the original GPS point was more than 3m from the marker. Six of the initial 36 permanent stands were deemed unsuitable due to recent events, such as logging, that rendered the survey markers unlocatable (i.e., lost or removed). Three stands (S5797B, S6797B and A0624) had one or more subplot plot markers missing and the missing plots were reconstructed from recorded distances (generally 20-m) and azimuths from the remaining markers, historic GPS points, and the hand drawn maps depicting land features. The resulting 30 selected stands were sampled as close as possible to the original sampling months and used the same protocols that were used when the plots were established in 1994/95.

Plot selection and sampling methodology are described in detail in Van Kley and Turner (2009). Originally, stands listed in the Forest Service inventory as being >60 yr in age were stratified by topographic position and a random selection of stands from that pool for each topographic type (Van Kley and Turner, 2009) were field-checked and accepted for sampling if they met minimal-disturbance criteria. The goal of the original project was to use as “natural” as possible examples of vegetation to develop the ECS. For the current study, available stands in two National Forests were classified by ECS type and an effort made to equally represent five generalized ECS types: 1) Arenic longleaf pine uplands, 2) Loamy dry mesic uplands, 3) Mesic lower slopes, terraces and stream bottoms, 4) Grossarenic and arenic dry uplands, and 5) Forested seeps (Table 2).

Each stand was demarked by four subplot marker points located at 20-m intervals along a transect. Each marker represented the center point of a series of nested plots: a 1-m^2 area nested within a 10-m^2 area, the 10-m^2 area nested within a 100-m^2 area, the 100-m^2 nested with a 250-m^2 circular area, and the totality of these sample areas nested within a 1000-m^2 search area. The 1000-m^2 boundary area extended 25-m on each side of the center point and 10-m along the transect on each side of the subplot center point. Boundaries were paced out, with care not to overlap adjacent plots. Ground-layer species (<1-m in height) in each subplot of increasing area was scored. An occurrence rank of

5 was given to herbaceous species in the 1-m^2 subplot, an occurrence rank of 4 was given to species in the 10-m^2 subplot but not found in the 1-m^2 subplot. Species growing in the 100-m^2 subplot were given a rank of 3, if not present in the 1-m^2 and 10-m^2 subplots, and species growing only in the 1000-m^2 area were given a rank of 2 if a small colony was identified or, alternatively, a 1 if only one or two individuals were present. Midstory species encompassed all woody species found within the 100-m^2 sample area having a height over 1-m and a diameter of less than 10-cm. Stems less than 5-cm diameter at breast height (dbh) and between 5- and 10-cm dbh were counted as small and large woody species, respectively, in the 100-m^2 subplot. Liana species were also identified if present in the subplot. The dbh for each occurrence of tree species with stems greater than 10-cm dbh were measured and counted in the 250-m^2 subplot as overstory species. A mean occurrence rank was calculated for each species and used in subsequent analyses. This method results in more objective datasets when the data is collected at different times by different individuals. Specimens that were unable to be identified in the field were collected, identified and any rare species deposited in the Stephen F. Austin State University herbarium. Certain taxa have interspecific differences that are seasonal and/or unclear and were subsequently lumped for the purposes of this study. *Quercus margarettiae* Ashe ex Small, *Quercus texana* Buckley and *Quercus falcata* Michx. are referred to herein as *Quercus falcata* Michx. *Vaccinium virgatum* Aiton was lumped with *Vaccinium elliottii* Chapman. *Cirsium horridulum* Michx. and *Cirsium*

carolinianum (Walt.) Fern. & Schub. are referred to as *Cirsium carolinianum* (Walt.) Fern. & Schub. Further, *Aureolaria grandiflora* (Benth.) Pennell and *Aureolaria pectinata* (Nutt.) Pennell are referred to as *Aureolaria pectinata* (Nutt.) Pennell.

Soil samples were collected from the four sample plots within each stand to a soil-layer depth of 10-cm with a trowel and transferred into a soil sample bag. Each soil sample was oven dried for 3 days in a Despatch LBB/LEB series oven at 100°F and sieved with a 2-mm mesh sieve to remove large stone pieces and root particles. Mechanical soil analysis was undertaken using the Bouyoucos method to determine soil texture (sand, silt and clay percentages). These percentages were averaged for each stand and soil texture identified and summarized in Table 3.

Physiological characteristics (slope, topographic position, etc.) were previously recorded in the original data set. Each stand was also evaluated for evidence of fire, feral hog activity and disturbance (Table 2). The scale for fire extends from a rank of 10, meaning extensively charred, blackened bark, or fire scars which would be indicative of recent and/or frequent fire and 0, i.e., no visible evidence of fire. A 10-point qualitative scale for disturbance was used where 10 equals recent visible evidence of disturbance and 0 reflects no visible evidence of recent disturbance. A new stand map was hand drawn for each stand to identify any new landmark features having arisen since the previous drawing. Seasonal changes were ignored in the present study as some species exhibit dominance in different seasons.

Table 2 - Ecosystem types and disturbance characteristics for the 30 upland forest stands from the Angelina and Sabine National Forests of Texas, U.S.A. Ecosystem types were established from samplings in 1994/95 and resampled in 2016. Disturbance was identified by Hogs = evidence of feral hog activity on a scale of 0 (none) to 10 (extreme), Fire = fire frequency estimated on a scale of 0 (none) to 10 (very frequent) and Level of disturbance = evidence of various non-hog disturbances on a scale of 0 (none) to 10 (extreme).

Stand	Ecosytem No.	Ecosystem type	Disturbance		
			Hogs	**Fire**	**Level**
A92B	1	Longleaf pine uplands (arenic)	0	8	0
A92C	1	Longleaf pine uplands (arenic)	0	8	0
A98C	1	Longleaf pine uplands (arenic)	0	6	0
A98F	1	Longleaf pine uplands (arenic)	0	6	0
A98G	1	Longleaf pine uplands (arenic)	0	6	0
A0624	2	Dry-mesic uplands (loamy)	0	8	0
A1113	2	Dry-mesic uplands (clay loam)	0	6	2
A1122	2	Dry-mesic uplands (loamy)	0	6	5
A1128	2	Dry-mesic uplands (loamy)	0	2	0
A2610	2	Dry-mesic uplands (loamy)	2	6	7
A2801C	2	Dry-mesic uplands (loamy)	0	4	6
A2801D	2	Dry-mesic uplands (loamy)	0	4	3
A1407	2	Dry-mesic uplands (loamy)	0	8	0
A0130	3	Mesic slopes and minor creek bottoms	0	2	0
A2010A	3	Mesic slopes and minor creek bottoms	10	0	6
A2010B	3	Mesic slopes and minor creek bottoms	6	0	6
A2025A	3	Mesic slopes and minor creek bottoms	0	0	5
A2801A	3	Mesic slopes and minor creek bottoms	0	0	3
S6797A	3	Mesic slopes and minor creek bottoms	0	0	1
S6797B	3	Mesic slopes and minor creek bottoms	0	0	1
S6797C	3	Mesic slopes and minor creek bottoms	0	0	1
S6797D	3	Mesic slopes and minor creek bottoms	0	0	1
S5113	4	Sandylands (grossarenic uplands)	0	8	0
S5201A	4	Sandylands (grossarenic uplands)	0	0	0
S5201B	4	Sandylands (grossarenic uplands)	0	0	0
S5297A	4	Sandylands (grossarenic uplands)	0	4	0
S5297B	4	Sandylands (grossarenic uplands)	0	7	0
A1612	5	Loamy and arenic forested seep	0	0	0
A1490	5	Mesic/forested seep	1	6	4
A76A	5	Loamy and arenic forested seep	1	0	1

ii. Statistical Analysis

Importance values were calculated for each species identified within each of the 30 stands for each stratum. Importance values for overstory and midstory stratum are based on relative basal area, relative density and relative frequency whereas importance values for the herbaceous stratum are based on relative occurrence, relative coverage and relative frequency.

An initial classification of the samples and species was completed using the importance values and a TWINSPAN (Hill and Šmilauer, 2005) analysis to establish trends in species pairing that occurred within the data. An additional multivariate analysis was subsequently used to further summarize the community data. Specifically, an ordination was carried out for 1994/1995 data and for the 2016 data for each vegetation stratum to identify ecosystem types. Environmental factors available for 1994/95 and collected in 2016 were included as explanatory vectors in each ordination, as appropriate. A Procrustes error analysis was used to overlay and compare the two ordinal sampling years and to indicate changes in ordinal space for each stand over the two sampling periods. All ordinations and Procrustes analyses were conducted in R using Non-metric Multidimensional Scaling (NMDS) ordination methods (McCune and Grace, 2002).

Species abundance curves were also calculated for sampling years separately to establish sampling heterogeneity for each stand within each vegetation stratum.

The Shannon Index (1) and Pielou's evenness (2) were calculated for each stand in each sample year and comparative two-sample t-tests conducted.

$$H' = -\sum_{i=1}^{s} p_i log_b p_i \qquad (1)$$

$$J = \frac{H\prime}{\log(specnumber)} \qquad (2)$$

Species richness was calculated and pooled. Absolute turnover (TA) and relative turnover rates (TR) were also calculated in accordance with Chepinoga, et al. (2012) as follows,

$$TA = \frac{(I+E)}{2t} \qquad (3)$$

$$TR = \left[\frac{(I+E)}{t(S_{\frac{1994}{95}}+S_{2016})}\right] x\ 100 \qquad (4)$$

Mean absolute turnover and relative turnover rates of each vegetation stratum among ecosystem types was subsequently compared using single factor Analysis of Variance (ANOVA, α = 0.05). The above analyses allowed for determination of turnover dependence based on ecosystem type. A non-significant interaction indicates that the effects of ecosystem type were independent, whereas a significant interaction indicates that the turnover was dependent on ecosystem type.

CHAPTER 5 - RESULTS

A total of 444 species were identified in the ground layer in both 1994/95 and 2016 for all 30 stands sampled. Of these species, 141 were identified only in 1994/95 and a total of 96 were identified only in 2016. The midstory comprised a total of 75 species with 56 being identified in both 1994/95 and 2016, six species were identified only in 1994/95 and 13 new species were identified in 2016. In the overstory, a total of 37 species were identified with 28 species being identified in 1994/95 and 2016. Four species were identified only in 1994/95 while five new species were identified in 2016. A complete list of species that were identified in each respective year is set out in the Appendix.

i. Ecosystem Analysis

A preliminary comparison between sampling periods for each stratum was completed to ascertain whether any differences in species pattern could be discerned between the data sets. Figures 4 to 6 graphically represent a ranked abundance of species collected for each stand. Rank-abundance curves can visually reveal differences in patterns of species richness and evenness. Figures 4 to 6 for each stratum appear to display symmetrically distributed species with comparable curve distributions for each collection period. These figures suggest that the number of species collected somewhat increased for the 2016 midstory and reduced for the 2016 herbaceous stratum. These results may be due to sampling discrepancies between sample years. In 1994/95 these stands were sampled by crews of two to six individuals, some solely dedicated to the identification of herbaceous species. However, only the author participated in sampling identification in these stands in 2016. Accordingly, although care was taken to identify species during similar sampling months, seasonal species may have been inadvertently omitted in some cases (e.g., ephemerals). Nevertheless, each stand generally displays floristic heterogeneity.

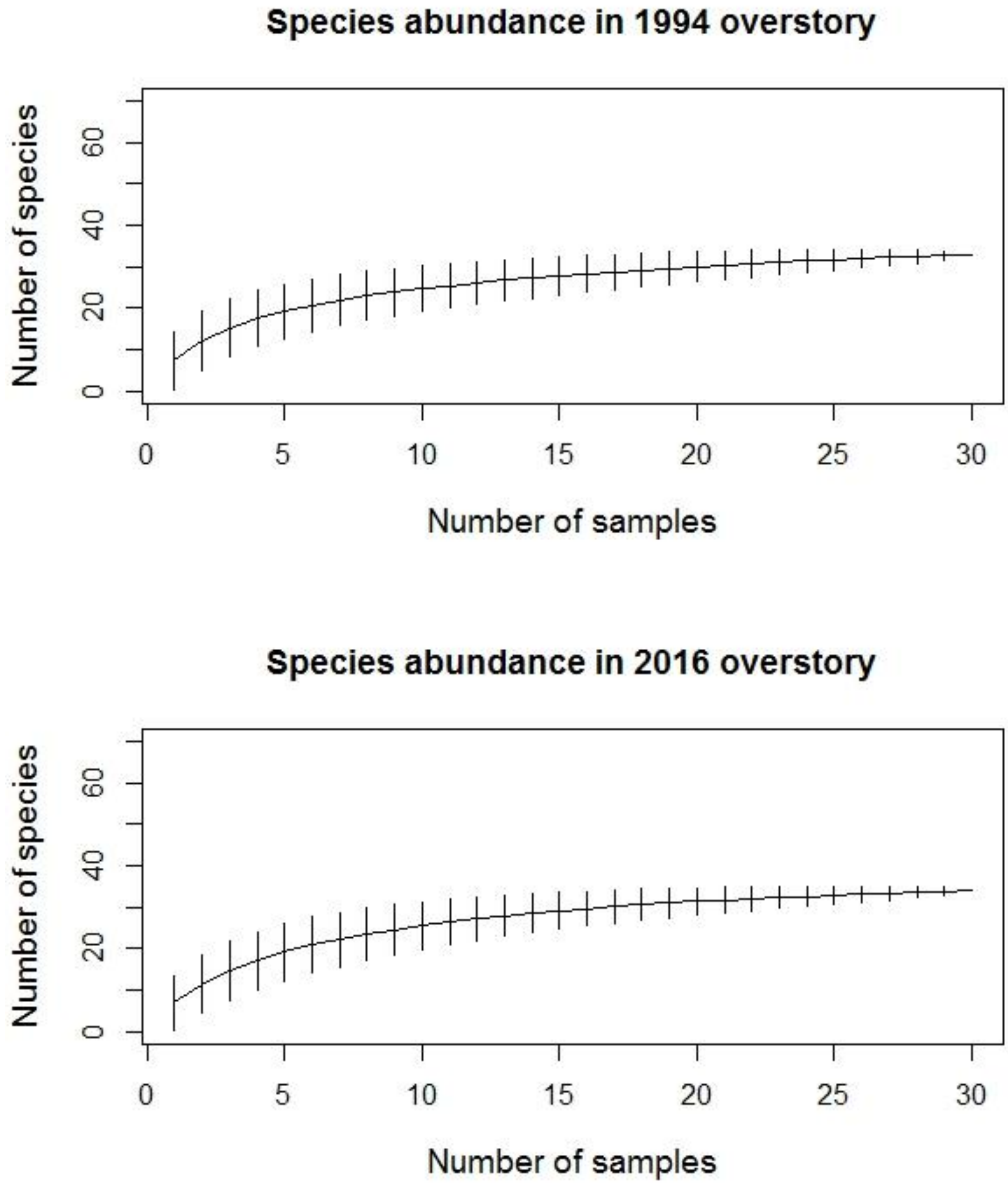

Figure 4 – Species abundance curves for overstory trees >10cm dbh for 30 upland forest stands from the Angelina and Sabine National Forests of Texas, U.S.A, sampled in 1994/95(a) and resampled in 2016(b).

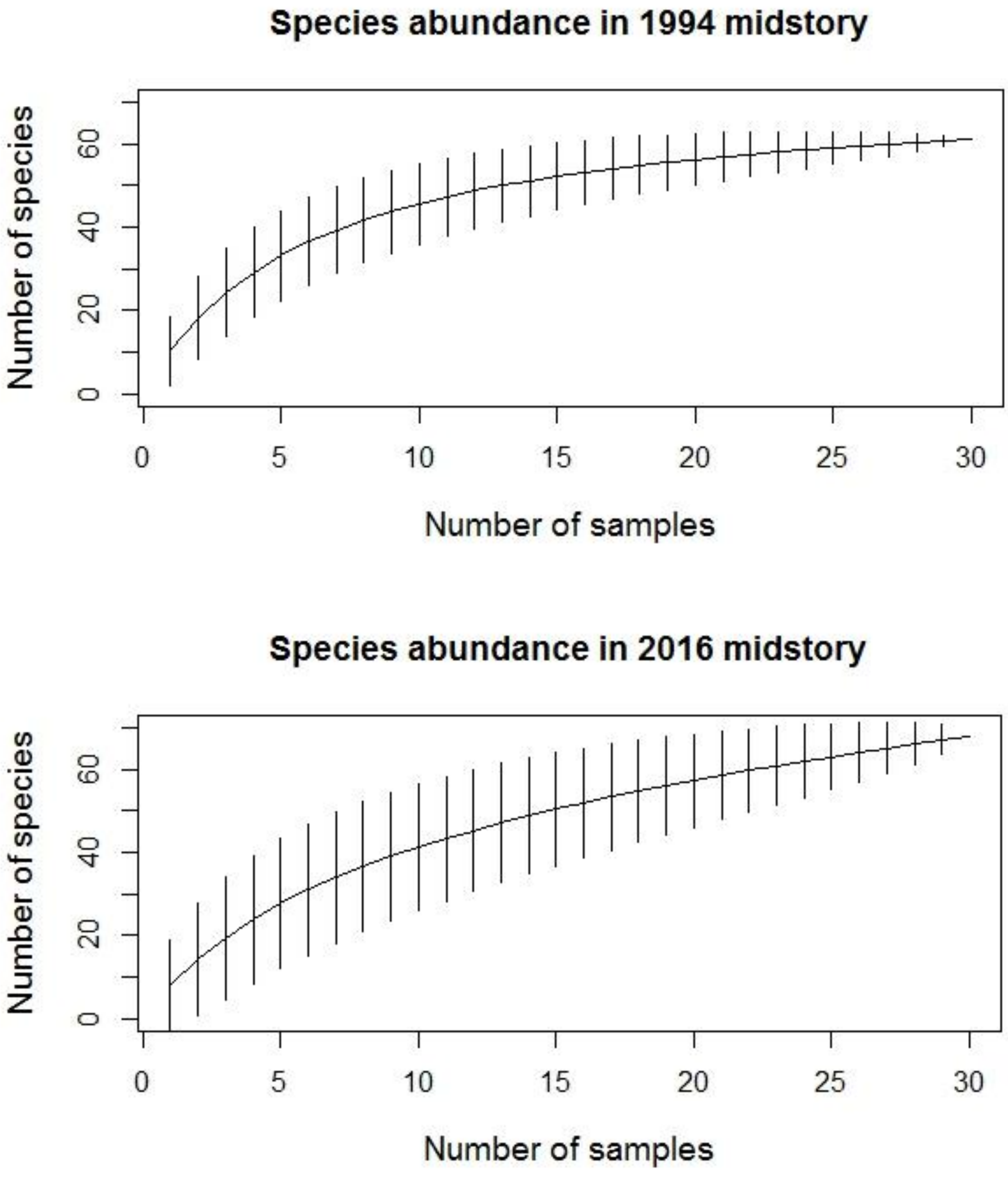

Figure 5 - Species abundance curves for midstory trees (>1m tall but <10cm dbh) for 30 upland forest stands from the Angelina and Sabine National Forests of Texas, U.S.A, sampled in 1994/95(a) and resampled in 2016(b).

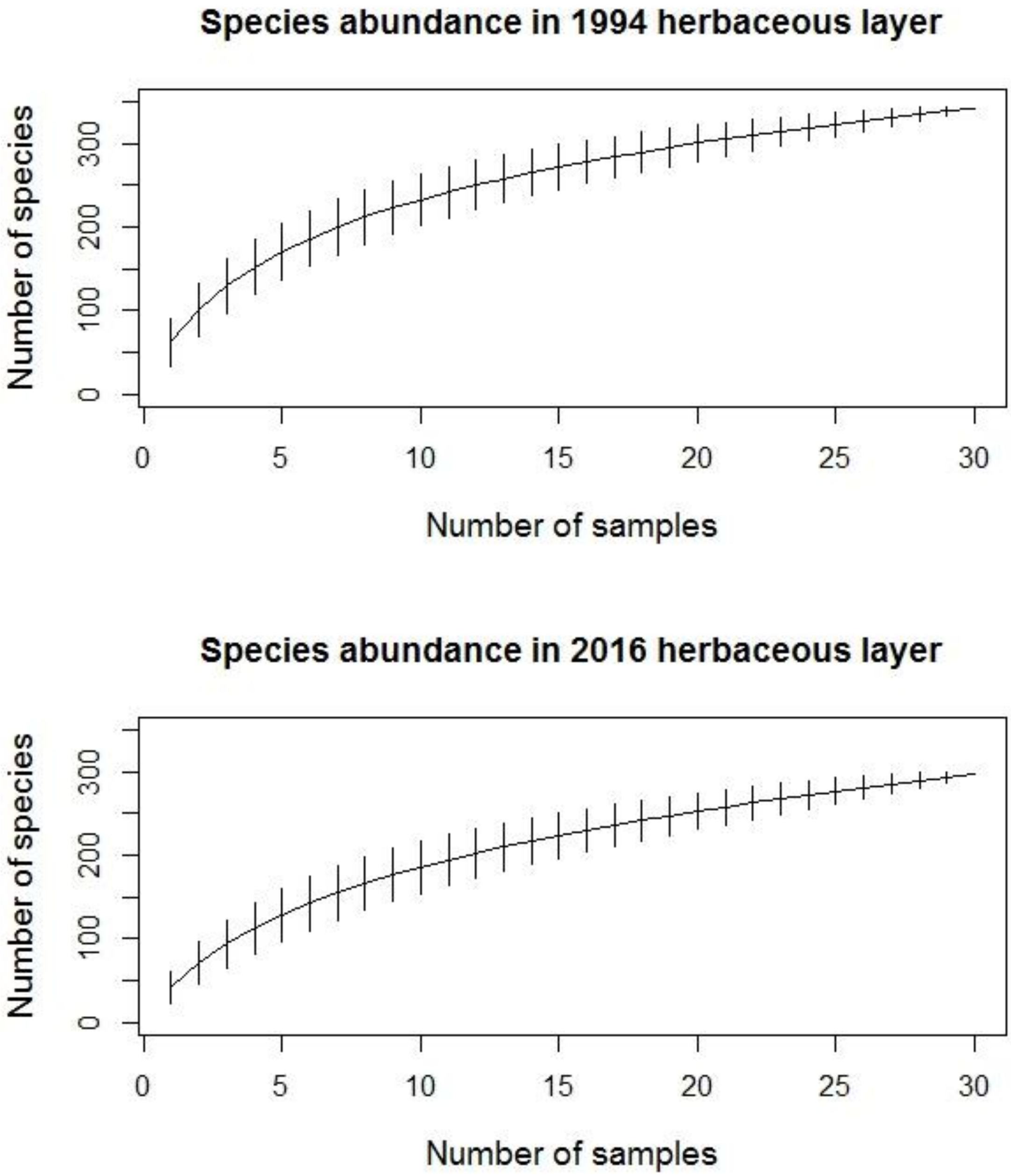

Figure 6 - Species abundance curves for herbaceous ground layer trees <1m tall) for 30 upland forest stands from the Angelina and Sabine National Forests of Texas, U.S.A, sampled in 1994/95(a) and resampled in 2016(b).

Table 3 - Soil characteristics for the 30 upland forest stands from the Angelina and Sabine National Forests of Texas, U.S.A, sampled in 2016 including county, family, taxonomic classification, drainage class, soil series, percentages of sand, clay and soil, and soil texture 10-cm from the surface.

Stand	County	Family	Taxonomic classification	Drainage Class	Soil series	Sand %	Clay %	Silt %	Surface Soil Texture (10-cm)
A92B	Angelina	Loamy, siliceous, semiactive	thermic Arenic Paleudults	well drained, moderately rapidly permeable	Letney	90	5	4	Sand
A92C	Angelina	Loamy, siliceous, semiactive	thermic Arenic Paleudults	well drained, moderately rapidly permeable	Letney	94	4	2	Sand
A98C	Angelina	Fine-loamy, siliceous, semiactive	thermic Typic Hapludults	well drained, moderately permeable soils	Stringtown	90	7	3	Sand
A98F	Angelina	Loamy, siliceous, semiactive,	thermic Arenic Paleudults	well drained, moderately rapidly permeable	Letney	90	5	5	Sand
A98G	Angelina	Loamy, siliceous, semiactive,	thermic Arenic Paleudults	well drained, moderately rapidly permeable	Letney	91	4	5	Sand
A0624	Angelina	Very-fine, smectitic	thermic Chromic Dystruderts	moderately well drained and very slowly permeable	LaCerda	62	14	24	Sandy loam
A1113	San Augustine	Fine, smectitic	thermic Chromic Vertic Hapludalfs	well drained, very slowly permeable	Eastwood	52	26	22	Sandy clay loam
A1122	San Augustine	Very-fine, smectitic	thermic Chromic Dystruderts	moderately well drained and very slowly permeable	LaCerda	69	14	17	Sandy loam
A1128	San Augustine	Fine, smectitic	thermic Chromic Vertic Hapludalfs	deep, well drained, very slowly permeable	Eastwood	83	8	9	Loamy sand
A2610	San Augustine	Fine, smectitic	thermic Chromic Dystruderts	deep, moderately well drained soils	Raylake	65	17	19	Sandy loam

Stand	County	Family	Taxonomic classification	Drainage Class	Soil series	Sand %	Clay %	Silt %	Surface Soil Texture (10-cm)
A2801C	San Augustine	Fine, mixed, semiactive/	thermic Typic Hapludults/	well drained and slowly to moderately slowly permeable	Cuthbert	85	7	8	Loamy sand
A2801D	San Augustine	Fine-loamy, siliceous, active	thermic Typic Glossaqualfs	poorly drained, slowly permeable	Mollville	79	10	11	Sandy loam
A1407	San Augustine	Very-fine, smectitic	thermic Vertic Hapludalfs	well drained and very slowly permeable	Moswell	84	6	10	Loamy sand
A2801A	San Augustine	Fine, mixed, semiactive	thermic Typic Hapludults	well drained and slowly to moderately slowly permeable	Cuthbert	76	9	15	Sandy loam
A0130	San Augustine	Fine, mixed, semiactive	thermic Typic Hapludults	well drained and slowly to moderately slowly permeable	Cuthbert	89	5	6	Sand
A2025A	San Augustine	Fine, mixed, semiactive/Fine -silty, siliceous, active-Fine-loamy, siliceous, active	thermic Typic Hapludults/thermic Typic Glossaqualfs-thermic Typic Glossudalfs	well drained and slowly to moderately slowly permeable/deep, poorly drained and very poorly drained, slowly permeable-deep, well drained, moderately permeable, loamy soils	Cuthbert/Guyton -Sawtown Complex	88	7	5	Loamy sand
A2010A	San Augustine	Fine-silty, siliceous, active-Fine-loamy, siliceous, active	thermic Typic Glossaqualfs- thermic Typic Glossudalfs	poorly drained and very poorly drained, slowly permeable- well drained, moderately permeable, loamy soils	Guyton-Sawtown Complex, mounded	84	6	9	Loamy sand
A2010B	San Augustine	Fine-silty, siliceous, active-Fine-loamy, siliceous, active	thermic Typic Glossaqualfs- thermic Typic Glossudalfs	poorly drained and very poorly drained, slowly permeable-deep, well drained, moderately permeable, loamy soils	Guyton-Sawtown Complex, mounded	81	7	13	Loamy sand

Stand	County	Family	Taxonomic classification	Drainage Class	Soil series	Sand %	Clay %	Silt %	Surface Soil Texture (10-cm)
S6797A	Sabine	Fine, kaolinitic	thermic Rhodic Paleudalfs	well drained, moderately slowly permeable	Nacogdoches	87	7	6	Loamy sand
S6797B	Sabine	Fine, kaolinitic	thermic Rhodic Paleudalfs	well drained, moderately slowly permeable	Nacogdoches	88	6	6	Loamy sand
S6797C	Sabine	Fine, mixed, active	thermic Mollic Hapludalfs	well drained, moderately slowly permeable	Trawick	93	4	3	Sand
S6797D	Sabine	Fine, mixed, active	thermic Mollic Hapludalfs	well drained, moderately slowly permeable	Trawick	91	6	3	Sand
S5113	San Augustine	Thermic, coated	Typic Quartzipsamments	excessively drained	Tonkawa	92	4	4	Sand
S5201A	San Augustine	Loamy, siliceous, semiactive	thermic Arenic Hapludults	well drained soils	Tenaha	97	2	1	Sand
S5201B	San Augustine	Thermic, coated	Typic Quartzipsamments	excessively drained	Tonkawa	92	4	4	Sand
S5297A	San Augustine	Thermic, coated	Typic Quartzipsamments	excessively drained	Tonkawa	95	4	1	Sand
S5297B	San Augustine	Fine, mixed, semiactive	thermic Typic Hapludults	well drained	Kirvin	95	3	2	Sand
A1612	San Augustine	Coarse-loamy, siliceous, active	thermic Fluvaquentic Dystrudepts	very deep, moderately well drained, moderately permeable	Iulus	79	4	17	Loamy sand
A1490	San Augustine	Loamy, siliceous, semiactive	thermic Arenic Plinthaquic Paleudults	moderately well drained soils	Rentzel	87	6	8	Loamy sand
A76A	Angelina	Siliceous	thermic Humaqueptic Psammaquents	poorly drained, rapidly permeable	Melhomes	93	3	4	Sand

Ordination is a multivariate technique that adapts a multidimensional swarm of community data points into low dimensional ordinal space (Pielou, 1984). Stand importance values for each species were projected in ordinal space by floristic similarity (points close together) and dissimilarity (points distanced apart) such that compositional patterns could be discerned. The resulting ordinal patterns were then used to broadly describe the relationship between species in terms of ecosystem types and to visualize underlying environmental factors that may be influencing these relationships. Ordination for the 30 stands of the current study were carried out separately by stratum for each sampling year to determine if any changes occurred between the two sampling periods. Figures 7 to 12 consistently indicate five separate ecosystem types (shown discriminated by polygons in the figures), representative of seven ecosystem landtypes for each strata. These groups correspond with the original classification of the stands into ecosystem types listed in Table 2. The ordinations for the overstory stratum appear to remain similar and stable between 1994/95 and 2016. However, moderate changes within ecosystem types seems to have occurred between sampling periods for the midstory and herbaceous layers, which may indicate an observable change in plant community composition occurred between sampling periods. Figures 13, 14 and 15 present a statistical shape analysis that plots the difference in point distributions in ordination space for each pair of samples between the sampling years and identifies the direction and strength of ordinal change. From these figures, it is evident each stratum exhibited some change between sample years, indicated by the arrow length. However, the length of the arrows, and therefore the direction and strength of change, appears the largest in the midstory and herbaceous layers.

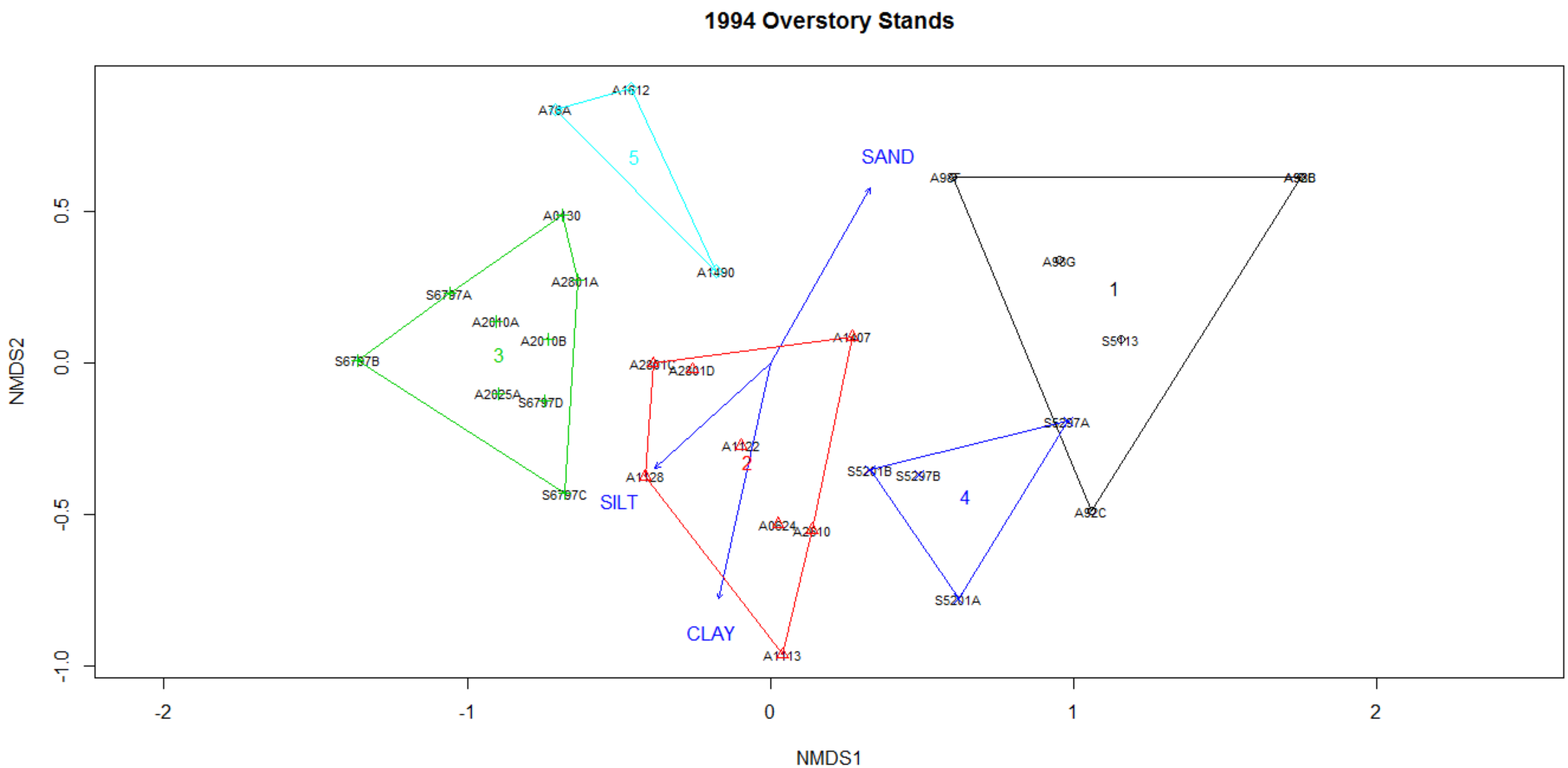

Figure 7 - A non-metric multidimensional scaling of the overstory of 30 upland forest stands from the Angelina and Sabine National Forests, Texas, USA sampled in 1994/95. Polygons show a classification of stands into ecosystem types: 1) Longleaf pine, 2) Dry-mesic, 3) Mesic, 4) Sandyland and 5) Forested seep. Joint-plot vectors indicate the direction and strength of environmental factors (only factors with r^2 >0.2 are plotted). Clay, silt, sand = percentage clay, silt and sand in the top 10-cm of soil.

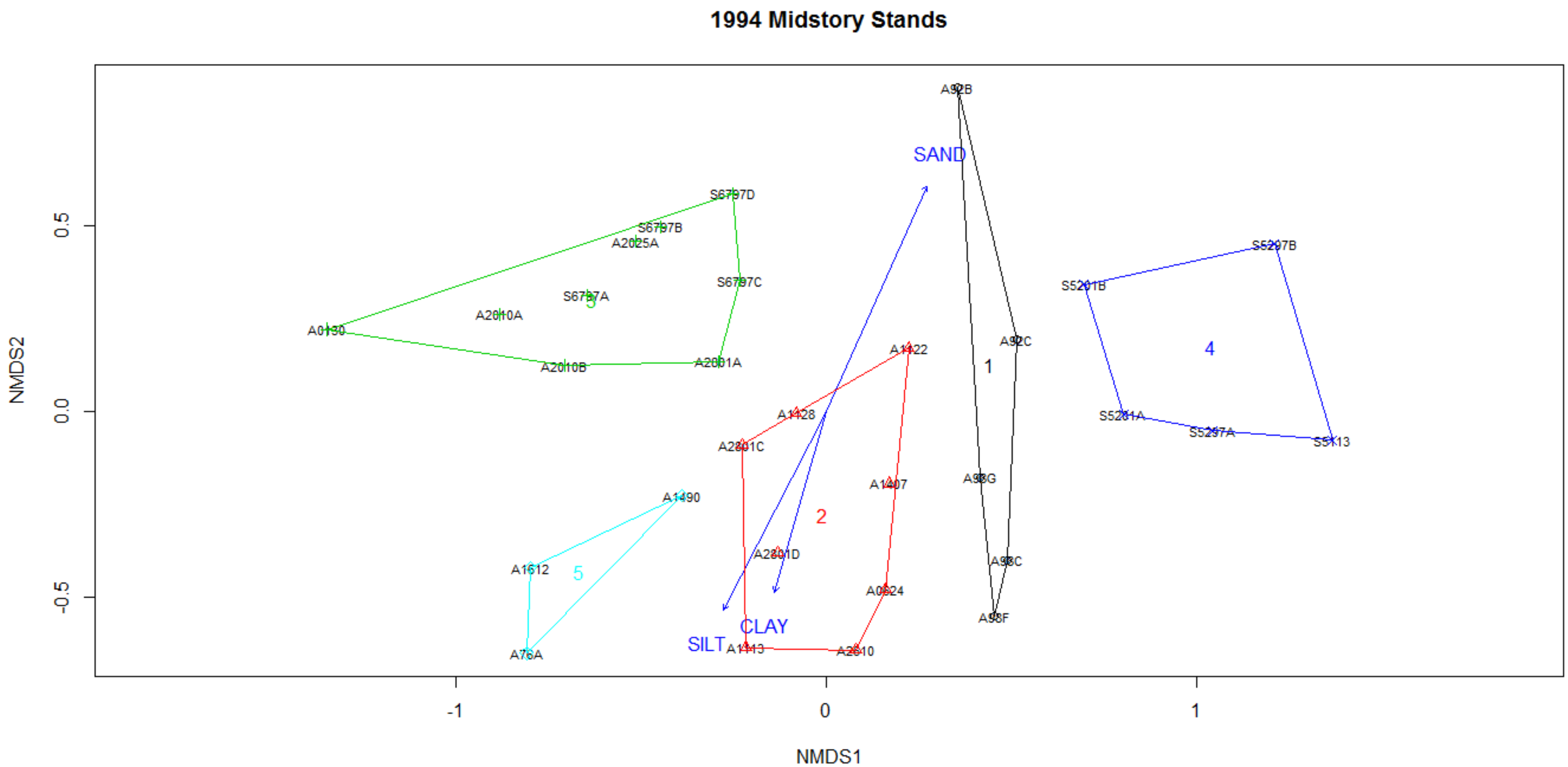

Figure 8 - A non-metric multidimensional scaling of the midstory of 30 upland forest stands from the Angelina and Sabine National Forests, Texas, USA sampled in 1994/95. Polygons show a classification of stands into ecosystem types: 1) Longleaf pine, 2) Dry-mesic, 3) Mesic, 4) Sandyland and 5) Forested seep. Joint-plot vectors indicate the direction and strength of environmental factors (only factors with r^2 >0.2 are plotted). Clay, silt, sand = percentage clay, silt and sand in the top 10-cm of soil.

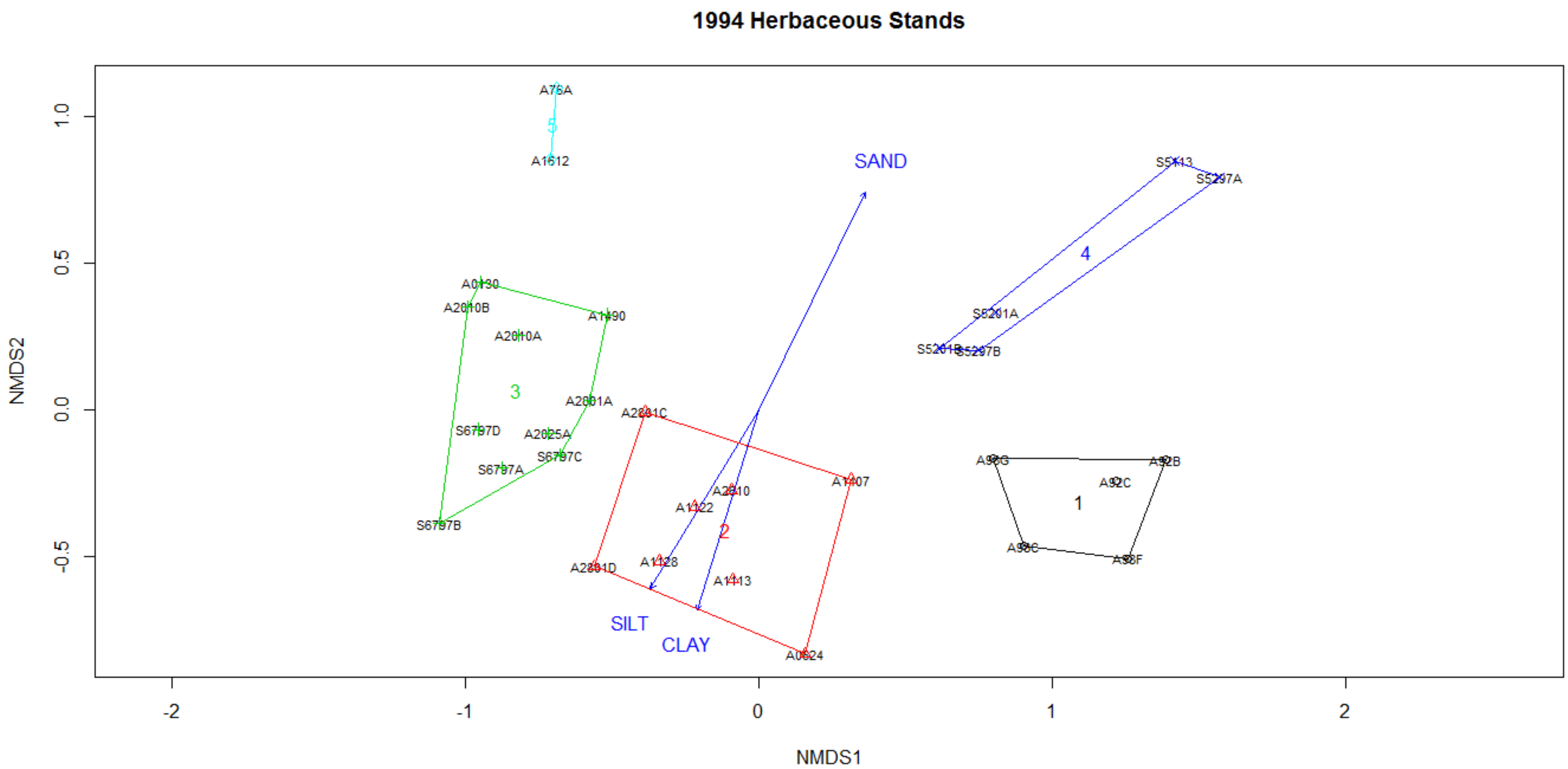

Figure 9 - A non-metric multidimensional scaling of the herbaceous layer of 30 upland forest stands from the Angelina and Sabine National Forests, Texas, USA sampled in 1994/95. Polygons show a classification of stands into ecosystem types: 1) Longleaf pine, 2) Dry-mesic, 3) Mesic, 4) Sandyland and 5) Forested seep. Joint-plot vectors indicate the direction and strength of environmental factors (only factors with r^2 >0.2 are plotted). Clay, silt, sand = percentage clay, silt and sand in the top 10-cm of soil.

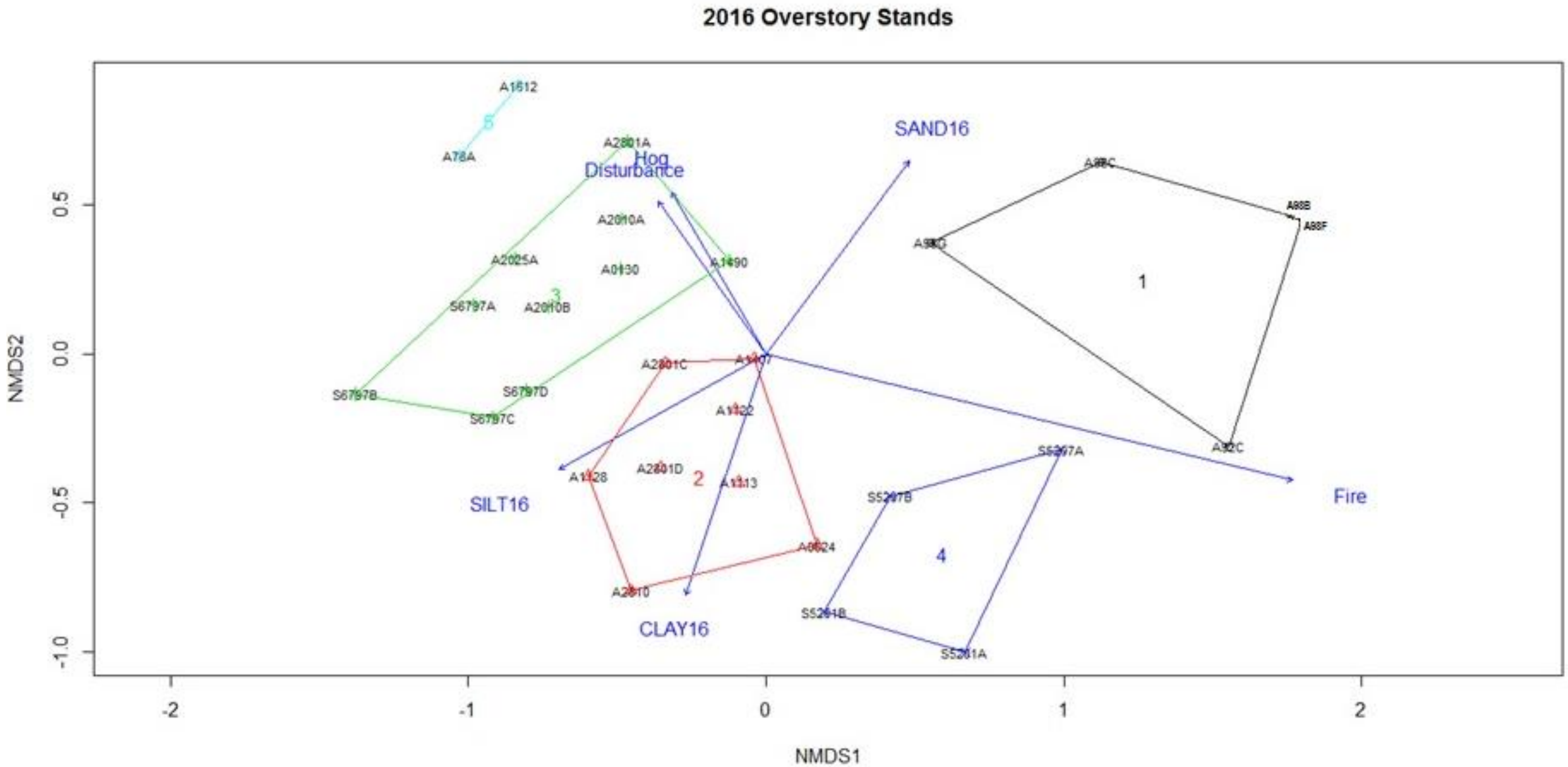

Figure 10 - A non-metric multidimensional scaling of the overstory of 30 upland forest stands from the Angelina and Sabine National Forests, Texas, USA sampled in 2016. Polygons show a classification of stands into ecosystem types: 1) Longleaf pine, 2) Dry-mesic, 3) Mesic, 4) Sandyland and 5) Forested seep. Joint-plot vectors indicate the direction and strength of environmental factors (only factors with r^2 >0.2 are plotted). Clay16, silt16 and sand16 = percentage clay, silt and sand in the top 10-cm of soil. Fire = fire frequency estimated on a scale of 0 (none) to 10 (very frequent). Hog = evidence of feral hog activity on a scale of 0 (none) to 10 (extreme), Disturbance = evidence of disturbance on a scale of 0 (none) to 10 (extreme).

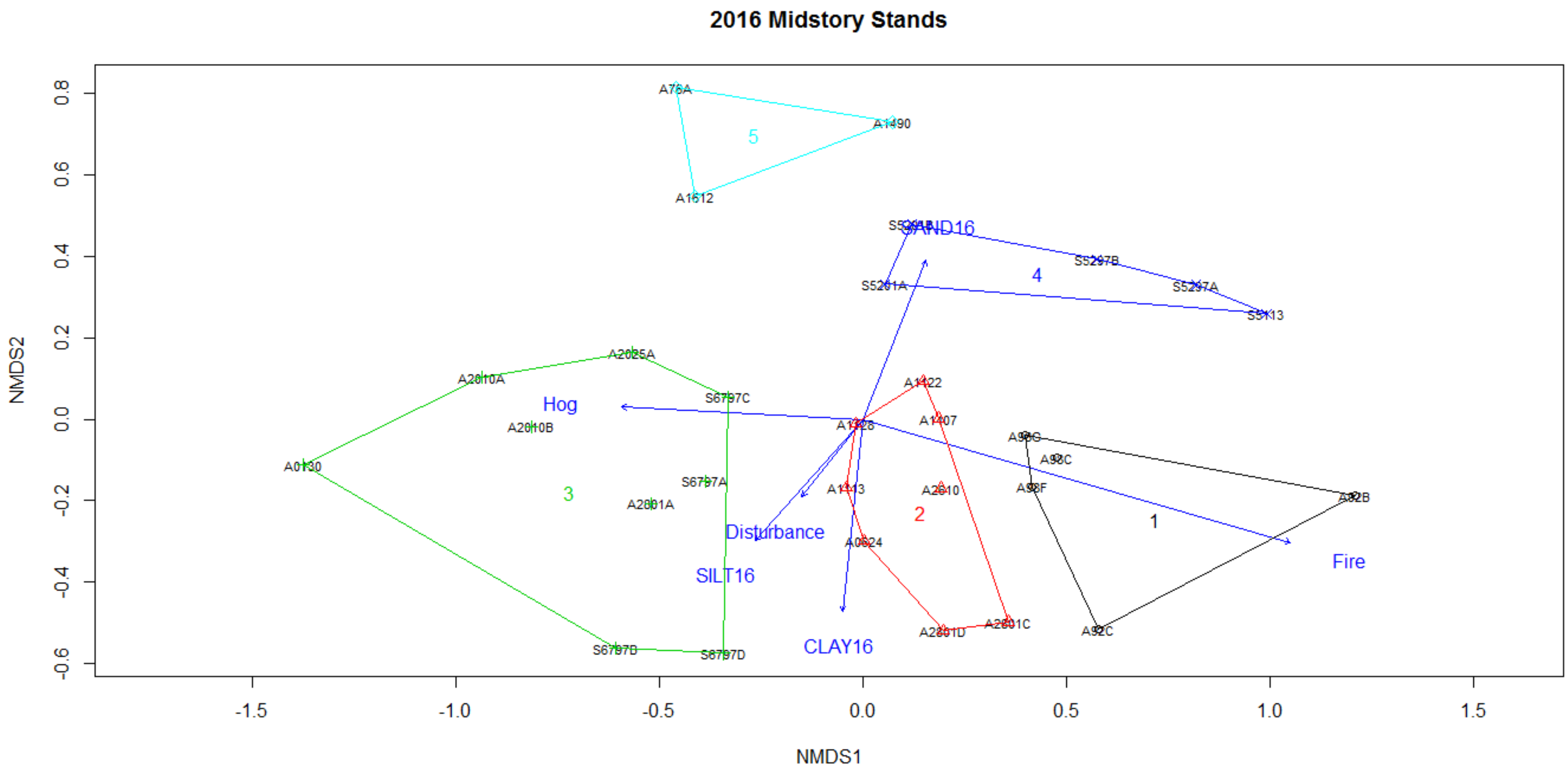

Figure 11 - A non-metric multidimensional scaling of the midstory of 30 upland forest stands from the Angelina and Sabine National Forests, Texas, USA sampled in 2016. Polygons show a classification of stands into ecosystem types: 1) Longleaf pine, 2) Dry-mesic, 3) Mesic, 4) Sandyland and 5) Forested seep. Joint-plot vectors indicate the direction and strength of environmental factors (only factors with r^2 >0.2 are plotted). Clay16, silt16 and sand16 = percentage clay, silt and sand in the top 10-cm of soil. Fire = fire frequency estimated on a scale of 0 (none) to 10 (very frequent). Hog = evidence of feral hog activity on a scale of 0 (none) to 10 (extreme), Disturbance = evidence of disturbance on a scale of 0 (none) to 10 (extreme).

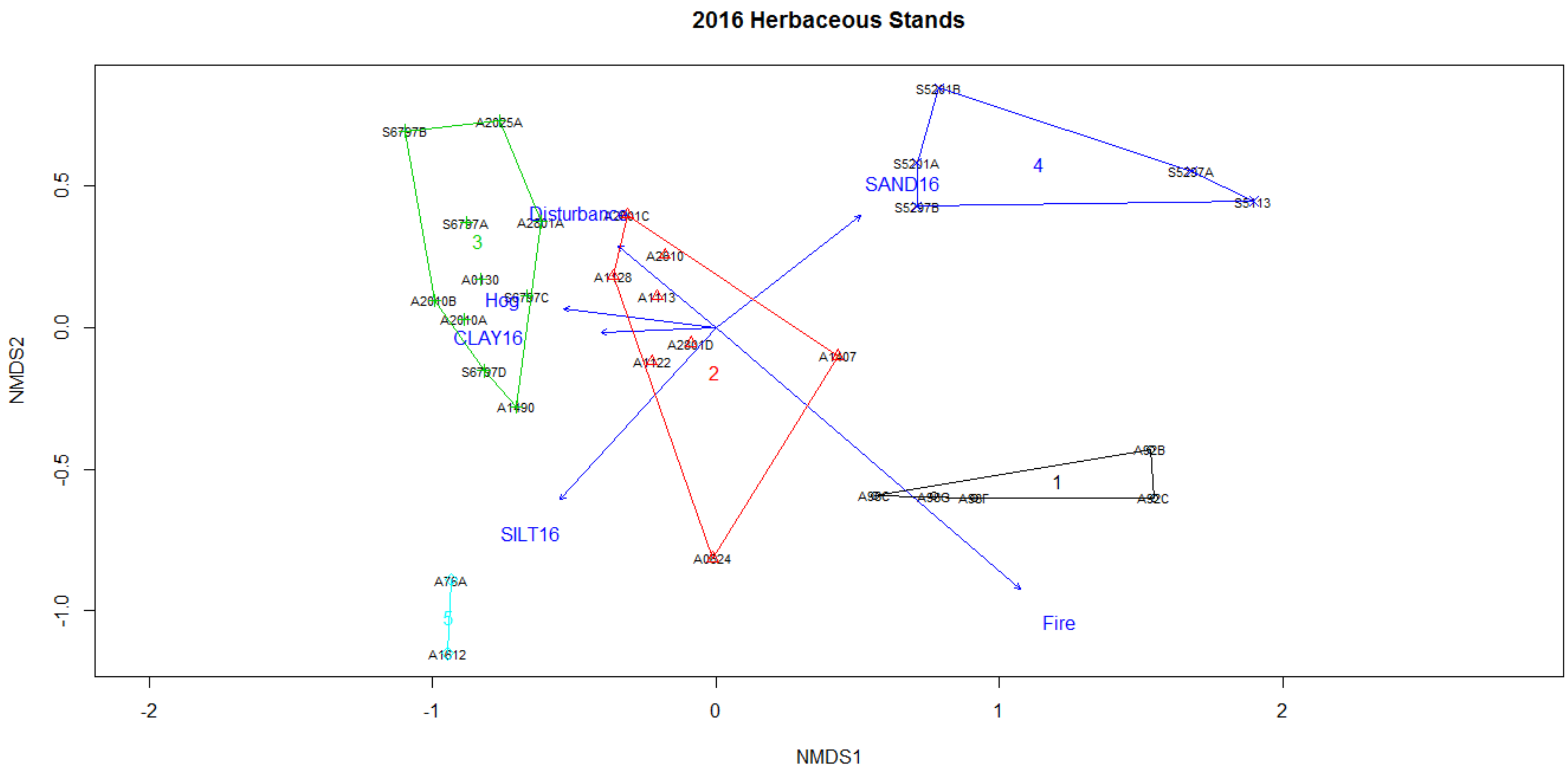

Figure 12 - A non-metric multidimensional scaling of the herbaceous layer of 30 upland forest stands from the Angelina and Sabine National Forests, Texas, USA sampled in 2016. Polygons show a classification of stands into ecosystem types: 1) Longleaf pine, 2) Dry-mesic, 3) Mesic, 4) Sandyland and 5) Forested seep. Joint-plot vectors indicate the direction and strength of environmental factors (only factors with r^2 >0.2 are plotted). Clay16, silt16 and sand16 = percentage clay, silt and sand in the top 10-cm of soil. Fire = fire frequency estimated on a scale of 0 (none) to 10 (very frequent). Hog = evidence of feral hog activity on a scale of 0 (none) to 10 (extreme), Disturbance = evidence of disturbance on a scale of 0 (none) to 10 (extreme).

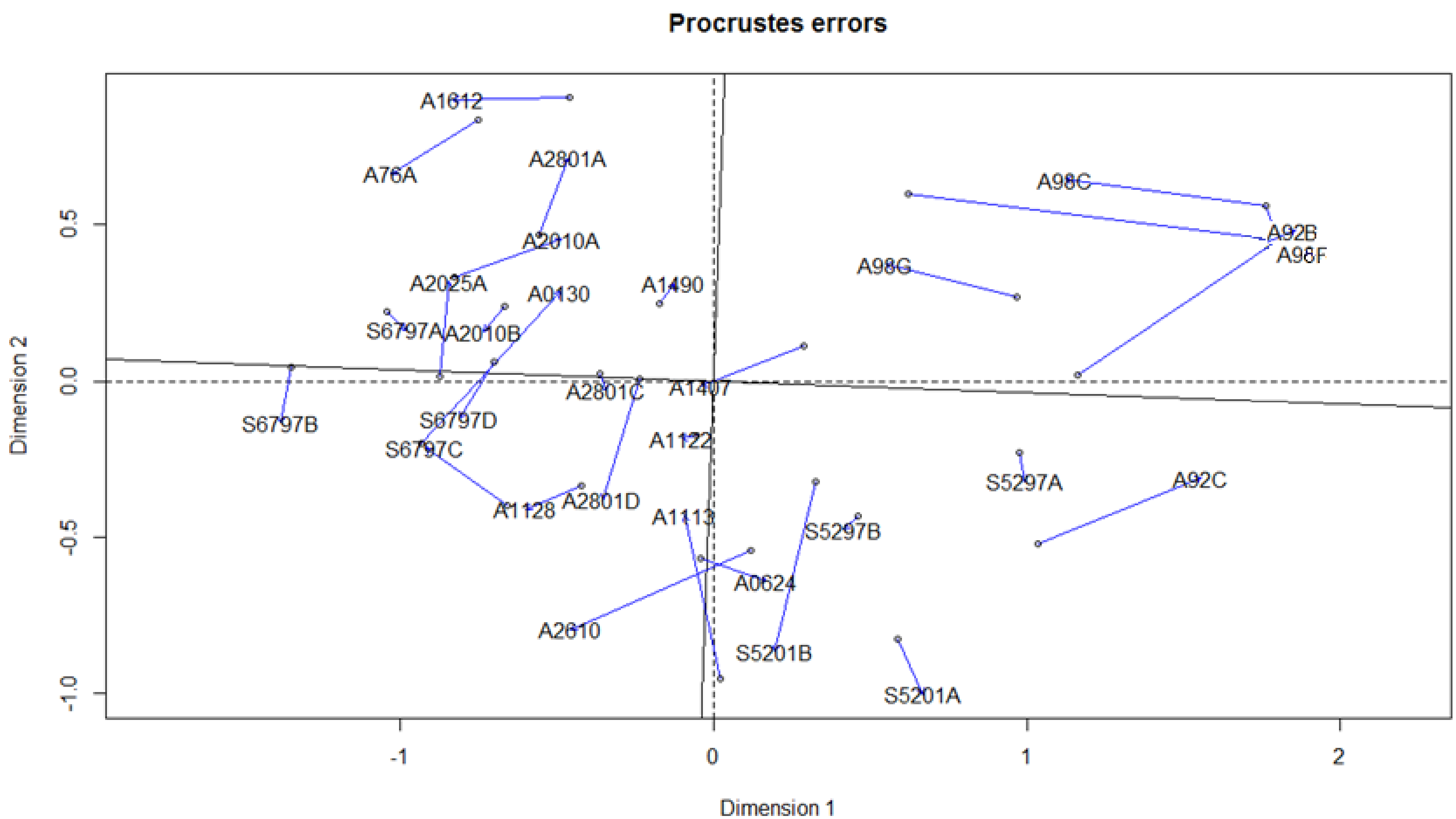

Figure 13 - A Procrustes analyses comparing the overstory of 30 upland forest stands from the Angelina and Sabine National Forests, Texas, USA sampled in 1994/95 and resampled in 2016. The point of origin indicated by a circle represents the ordinal point for each sample site in 1994/95. The line extending from each ordinal point expresses the direction of ordinal change from the point of origin and the arrow head indicates the strength of the ordinal change from 1994/95 to 2016. The goodness of fit m^2 Gower statistic = 5.53, Protest = 0.001 indicating the two data sets exhibit greater concordance than expected at random.

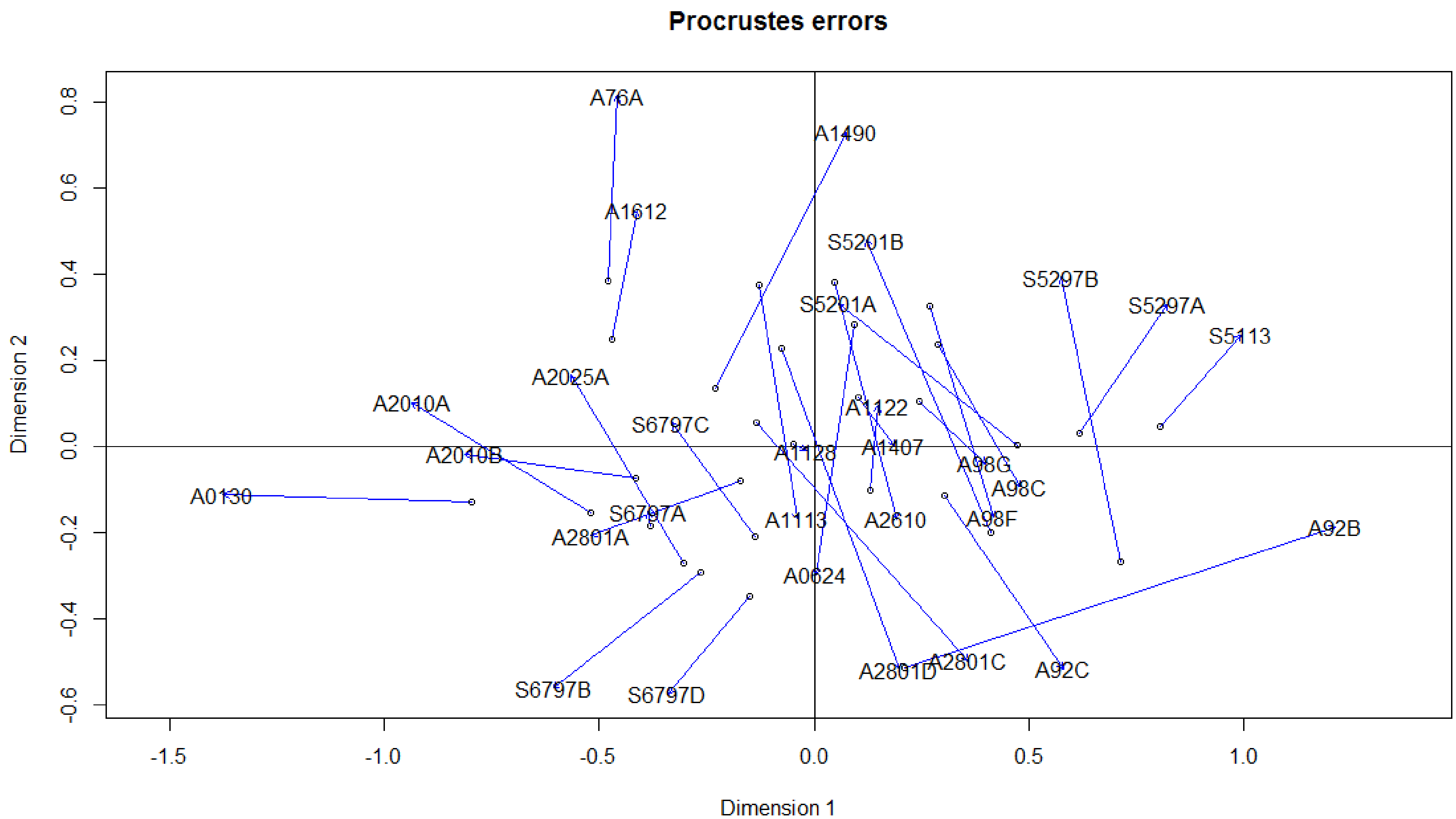

Figure 14 - A Procrustes analyses comparing the midstory of 30 upland forest stands from the Angelina and Sabine National Forests, Texas, USA sampled in 1994/95 and resampled in 2016. The point of origin indicated by a circle represents the ordinal point for each sample site in 1994/95. The line extending from each ordinal point expresses the direction of ordinal change from the point of origin and the arrow head indicates the strength of the ordinal change from 1994/95 to 2016. The goodness of fit m² Gower statistic = 7.76, Protest = 0.001 indicating the two data sets exhibit greater concordance than expected at random.

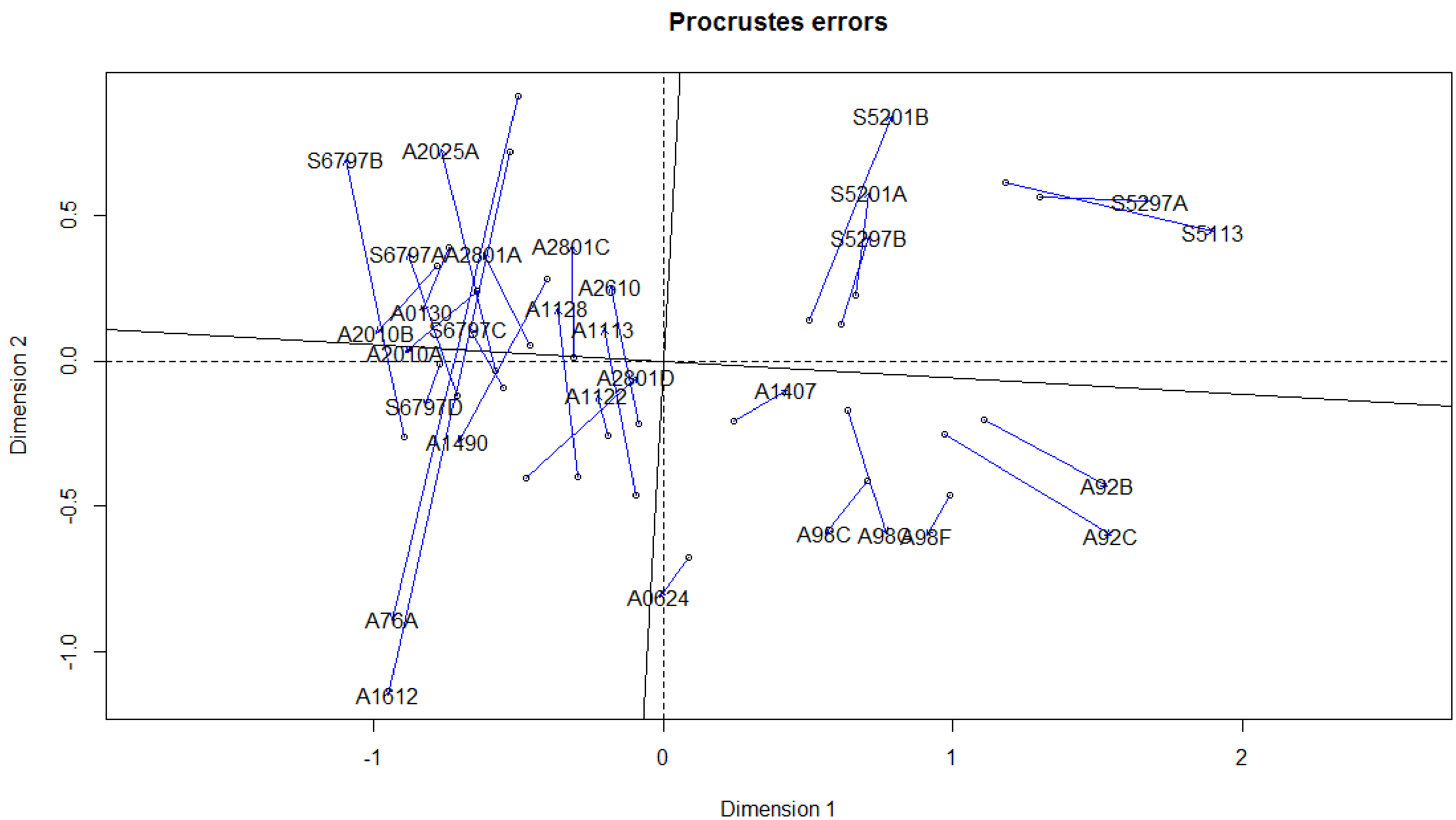

Figure 15 - A Procrustes analyses comparing the herbaceous layer of 30 upland forest stands from the Angelina and Sabine National Forests, Texas, USA sampled in 1994/95 and resampled in 2016. The point of origin indicated by a circle represents the ordinal point for each sample site in 1994/95. The line extending from each ordinal point expresses the direction of ordinal change from the point of origin and the arrow head indicates the strength of the ordinal change from 1994/95 to 2016. The goodness of fit m² Gower statistic = 13.17, Protest = 0.001indicating the two data sets exhibit greater concordance than expected at random.

ii. Ecosystem Types

Analyses of the above species relationships, soil, and topographic data strongly supported classification of the 2016 sample stands into the five generalized ecosystem types of 1994/95. Ecosystem 1 encompasses the arenic dry uplands ("Longleaf pine uplands"), ecosystem 2 comprises the loamy dry-mesic and clayey dry-mesic uplands ("Dry-mesic uplands"), ecosystem 3 includes the mesic slopes and mesic stream bottoms ("Mesic"), ecosystem 4 is characteristic of grossarenic and arenic dry uplands ("Sandylands") and ecosystem 5 is characteristic of the forested seeps ("Forested seep").

The Longleaf pine uplands ecosystem type (ecosystem 1) occurs on gentle sloping to steep upland areas having arenic soils, including the Letney and Springtown soils series found at these stands. These soils are deep, well drained and moderately rapidly permeable (Table 3). Fire is also a common disturbance in these areas due to current forest management practices (Table 2, Figures 10, 11 and 12). Accordingly, longleaf pine (*Pinus palustris* P. Mill.) is a dominant tree as it grows well on sandy soils, especially with periodic fire episodes which selects for this species. However, oaks (e.g., *Quercus stellata* Wangenh.) can also be found scattered within these areas. A common shrub is winged sumac (*Rhus copallinum* L.) which is tolerant of coarse to fine soil textures. The ground flora is varied and includes species such as little bluestem (*Schizachyrium scoparium* (Michx.) Nash) and Pickering's dawnflower (*Stylisma* *pickeringii* (Torr. ex M.A. Curtis) Gray). Other species characteristics of this ecosystem type are set out in Table 4.

The Sandyland ecosystem stands (ecosystem 2) are characterized by Tonkawa and Tenaha soils which are sandy soils that are excessively drained and well drained, respectively, having only a very shallow loamy subsoil, if present. These xeric sands have limited ability to hold moisture resulting in an open forest canopy of pines (e.g., *Pinus palustris* P. Mill., *Pinus echinata* P. Mill., *Pinus taeda* L.) and of midstory of oak species (*Quercus incana* Bartr., *Quercus margarettiae* Ashe ex Small). Common ground flora includes species such as brackenfern (*Pteridium aquilinum* (L.) Kuhn) and little bluestem (*Schizachyrium scoparium* (Michx.) Nash). Fire management was also apparent in these stands, similar to the Longleaf pine upland ecosystems (Table 2, Figures 10, 11 and 12). Table 5 sets out other common herbaceous species identified in these stands.

The Mesic slopes and stream bottom ecosystem stands (ecosystem 3; Table 6) are mesic slopes that tend to lower slopes stream adjacent and narrow floodplains of small stream tributaries. The soil texture for these mesic stands is typically sand and comprises a mix or a complex of varying soil types that range from poorly drained to well-drained (Table 3). Mixes of pine and hardwood communities develop on these soils as disturbance generally tends to be lower in these areas while nutrient and moisture availability is typically higher. Loblolly pine (*Pinus taeda* L.) and white oak (*Quercus alba* L.) are common dominant species in these stands while Eastern American hop hornbeam (*Ostrya virginiana*

(P. Mill.) K. Koch) and blackgum (*Nyssa sylvatica* Marsh.) are typically found in the midstory of these undisturbed areas. Ground flora for this ecosystem type includes vines such as muscadine grape (*Vitis rotundifolia* Michx.) and greenbriar (*Smilax pumila* Walt.).

Moderate to slowly permeable soils are typical of the Dry-mesic uplands ecosystem type (ecosystem 4). The soil series LaCerda, Eastwood, Raylake, Cuthbert and Mollville (Table 3) found in these areas comprise clay loams, sandy loams or shallow loam surfaces that retain moisture well. This ecosystem type is the most widespread in the Pineywoods (Van Kley, 2007). Loblolly pine (*Pinus taeda* L.) is a dominant tree, typical on the loamy soils, whereas shortleaf pine (*Pinus echinata* P. Mill.) is often the dominant tree in the clay loam soils. Shrubs and midstory trees common to this ecosystem include American beautyberry (*Callicarpa americana* L.), yaupon (*Ilex vomitoria* Ait.) and red maple (*Acer rubrum* L.). Poison ivy (*Toxicodendron radicans* (L.) Kuntze) and partridge berry (*Mitchella repens* L.) are typically found in the ground flora (Table 7).

The Forested seep stands (ecosystem 5) tend to share species in common with more than one of the above ecosystem types resulting a unique group having an array of soil types that are different for each stand, if only slightly in soil properties (Table 3). For example, the Iulus and Rentzel soil series are moderately well-drained and are very deep soil series that have a loamy sand texture. The Melhomes soil series is also a deep soil series but consists of poorly drained sand. The dominant tree species for these stands appears to be loblolly pine (*Pinus taeda* L.) and blackgum (*Nyssa sylvatica* Marsh.). However, the midstory strata of these stands only finds agreement of common species in one stand between 1994/95 and 2016, namely, the large gallberry (*Ilex coriacea* (Pursh) Chapman*;* A76A). The herbaceous layer only finds common agreement between sampling years relating to the greenbriar (*Smilax pumila* Walt.) in stand A1490 (Table 8). Accordingly, this ecosystem type tends to illustrate a dynamic plasticity that isolates this ecosystem type from the remaining ecosystem types identified in the present study.

Table 4 – A summary of species indicated as having the highest importance value (IV) in each of the 5 Longleaf pine ecosystem types identified from 30 upland forest stands in the Angelina and Sabine National Forests, Texas, USA, sampled in 1994/95 and resampled in 2016. Species frequency (FREQ), percent relative frequency (RFREQ%), percent relative basal area (RBA%) and percent relative density (RDEN%) are shown for the overstory and midstory. Species frequency (FREQ), percent relative frequency (RFREQ%), percent relative occurrence (ROC%) and percent relative coverage (RCOV%) are shown for the herbaceous layer.

OVERSTORY												
1994							2016					
STAND	**SPECIES**	**FREQ**	**RFREQ %**	**RBA %**	**RDEN %**	**IV**	**SPECIES**	**FREQ**	**RFREQ %**	**RBA %**	**RDEN %**	**IV**
A92B	*Pinus palustris* P. Mill.	4	100.0	100.0	100.0	100.0	*Pinus palustris P. Mill.*	4	100.0	100.0	100.0	100.0
A92C	*Quercus stellata* Wangenh.	4	57.1	72.4	88.9	72.8	*Quercus stellata* Wangenh.	4	57.1	73.1	87.5	72.6
A98C	*Pinus palustris* P. Mill.	4	100.0	100.0	100.0	100.0	*Pinus palustris* P. Mill.	4	80.0	99.8	98.1	92.6
A98F	*Pinus palustris* P. Mill.	4	57.1	84.1	91.4	77.6	*Pinus palustris* P. Mill.	4	100.0	100.0	100.0	100.0
A98G	*Pinus palustris* P. Mill.	3	37.5	52.6	36.1	42.1	*Pinus taeda* L.	3	42.9	57.0	60.0	53.3

MIDSTORY												
1994							2016					
STAND	**SPECIES**	**FREQ**	**RFREQ %**	**RBA %**	**RDEN %**	**IV**	**SPECIES**	**FREQ**	**RFREQ %**	**RBA %**	**RDEN %**	**IV**
A92B	*Sassafras albidum* (Nutt.) Nees	4	50.0	60.4	60.4	56.9	*Rhus copallinum* L.	2	40.0	76.9	76.9	64.6
A92C	*Callicarpa americana* L.	1	12.5	23.5	40.0	25.3	*Callicarpa americana* L.	2	33.3	60.0	60.0	51.1
A98C	*Pinus palustris* P. Mill.	2	13.3	19.2	23.1	18.5	*Ilex vomitoria* Ait.	3	37.5	36.8	36.8	37.1
A98F	*Pinus taeda* L.	3	20.0	28.8	42.2	30.3	*Pinus palustris* P. Mill.	3	33.3	50.0	50.0	44.4
A98G	*Pinus palustris* P. Mill.	4	21.1	28.5	25.4	25.0	*Pinus taeda* L.	3	18.8	53.0	58.5	43.4

HERB												
1994							2016					
STAND	**SPECIES**	**FREQ**	**RFREQ %**	**ROC %**	**RCOV %**	**IV**	**SPECIES**	**FREQ**	**RFREQ %**	**ROC %**	**RCOV %**	**IV**
A92B	*Stylisma pickeringii* (Torr. ex M.A. Curtis) Gray	4	2.2	3.3	41.6	15.7	*Schizachyrium scoparium* (Michx.) Nash	4	3.0	4.7	15.7	7.8
A92C	*Andropogon gerardii* Vitman	4	1.9	2.8	24.1	9.6	*Schizachyrium scoparium* (Michx.) Nash	4	6.0	8.6	59.5	24.7
A98C	*Gelsemium sempervirens* St.-Hil.	4	2.2	3.0	19.9	8.4	*Ilex decidua* Walt.	3	3.4	4.6	24.2	10.7
A98F	*Pteridium aquilinum* (L.) Kuhn	2	1.0	1.1	15.4	5.8	*Schizachyrium scoparium* (Michx.) Nash	4	3.7	6.3	25.0	11.7
A98G	*Schizachyrium scoparium* (Michx.) Nash	4	2.4	3.7	9.0	5.0	*Schizachyrium scoparium* (Michx.) Nash	4	4.5	6.8	32.0	14.4

Table 5 - A summary of species indicated as having the highest importance value (IV) in each of the 5 sandyland ecosystem types identified from 30 upland forest stands in the Angelina and Sabine National Forests, Texas, USA, sampled in 1994/95 and resampled in 2016 Species frequency (FREQ), percent relative frequency (RFREQ%), percent relative basal area (RBA%) and percent relative density (RDEN%) are shown for the overstory and midstory. Species frequency (FREQ), percent relative frequency (RFREQ%), percent relative occurrence (ROC%) and percent relative coverage (RCOV%) are shown for the herbaceous layer.

OVERSTORY												
1994							2016					
STAND	**SPECIES**	**FREQ**	**RFREQ %**	**RBA %**	**RDEN %**	**IV**	**SPECIES**	**FREQ**	**RFREQ %**	**RBA %**	**RDEN %**	**IV**
S5113	*Pinus palustris* P. Mill.	4	66.7	91.8	78.9	79.1	*Pinus palustris* P. Mill.	4	100.0	100.0	100.0	100.0
S5201A	*Pinus echinata* P. Mill.	4	26.7	33.4	52.5	37.5	*Pinus echinata* P. Mill.	4	40.0	50.3	59.4	49.9
S5201B	*Pinus echinata* P. Mill.	4	22.2	48.4	29.8	33.5	*Pinus echinata* P. Mill.	3	20.0	50.1	22.2	30.8
S5297A	*Pinus palustris* P. Mill.	3	37.5	68.4	45.5	50.4	*Pinus palustris* P. Mill.	3	33.3	79.6	44.4	52.5
S5297B	*Pinus taeda* L.	4	25.0	54.7	33.3	37.7	*Pinus taeda* L.	4	33.3	72.7	48.8	51.6

MIDSTORY												
1994							2016					
STAND	**SPECIES**	**FREQ**	**RFREQ %**	**RBA %**	**RDEN %**	**IV**	**SPECIES**	**FREQ**	**RFREQ %**	**RBA %**	**RDEN %**	**IV**
S5113	*Quercus incana* Bartr.	2	50.0	92.8	88.5	77.1	*Quercus incana* Bartr.	4	50.0	42.1	60.7	51.0
S5201A	*Sassafras albidum* (Nutt.) Nees	4	14.8	23.3	33.9	24.0	*Acer rubrum* L.	4	21.1	24.8	21.5	22.5
S5201B	*Quercus margarettiae* Ashe ex Small	4	18.2	50.7	50.5	39.8	*Quercus margarettiae* Ashe ex Small	4	25.0	77.1	45.2	49.1
S5297A	*Quercus margarettiae* Ashe ex Small	3	17.6	59.1	37.8	38.2	*Quercus incana* Bartr.	4	26.7	56.9	56.8	46.8
S5297B	*Quercus incana* Bartr.	4	57.1	63.3	60.0	60.1	*Quercus incana* Bartr.	3	18.8	37.3	42.4	32.8

HERB												
1994							2016					
STAND	**SPECIES**	**FREQ**	**RFREQ %**	**ROC %**	**RCOV %**	**IV**	**SPECIES**	**FREQ**	**RFREQ %**	**ROC %**	**RCOV %**	**IV**
S5113	*Stylisma pickeringii* (Torr. ex M.A. Curtis) Gray	4	4.8	7.2	27.8	13.3	*Schizachyrium scoparium* (Michx.) Nash	3	2.9	4.4	36.2	14.5
S5201A	*Pteridium aquilinum* (L.) Kuhn	4	2.4	3.5	40.5	15.5	*Pteridium aquilinum* (L.) Kuhn	4	4.5	6.8	21.3	10.9
S5201B	*Pteridium aquilinum* (L.) Kuhn	4	2.8	3.5	15.9	7.4	*Vitis rotundifolia* Michx.	4	4.7	6.0	19.6	10.1
S5297A	*Schizachyrium scoparium* (Michx.) Nash	4	4.8	7.5	46.1	19.5	*Schizachyrium scoparium* (Michx.) Nash	4	4.9	7.2	34.1	15.4
S5297B	*Pteridium aquilinum* (L.) Kuhn	4	2.6	4.3	46.2	17.7	*Pteridium aquilinum* (L.) Kuhn	4	4.3	6.2	44.4	18.3

Table 6 - A summary of species indicated as having the highest importance value (IV) in each of the 9 mesic slope ecosystem types identified from 30 upland forest stands in the Angelina and Sabine National Forests, Texas, USA, sampled in 1994/95 and resampled in 2016. Species frequency (FREQ), percent relative frequency (RFREQ%), percent relative basal area (RBA%) and percent relative density (RDEN%) are shown for the overstory and midstory. Species frequency (FREQ), percent relative frequency (RFREQ%), percent relative occurrence (ROC%) and percent relative coverage (RCOV%) are shown for the herbaceous layer.

OVERSTORY												
1994							2016					
STAND	**SPECIES**	**FREQ**	**RFREQ %**	**RBA %**	**RDEN %**	**IV**	**SPECIES**	**FREQ**	**RFREQ %**	**RBA %**	**RDEN %**	**IV**
A2801A	*Ostrya virginiana* (P. Mill.) K. Koch	3	15.0	15.1	24.3	18.1	*Nyssa sylvatica* Marsh.	3	17.6	23.3	26.5	22.5
A0130	*Pinus taeda* L.	4	16.7	65.9	26.2	36.3	*Pinus taeda* L.	4	22.2	51.2	27.0	33.5
A2025A	*Quercus alba* L.	4	17.4	44.2	15.4	25.6	*Quercus alba* L.	2	9.5	42.3	9.8	20.5
A2010A	*Pinus taeda* L.	3	14.3	55.8	14.8	28.3	*Ilex opaca* Ait.	4	25.0	12.2	54.3	30.5
A2010B	*Pinus taeda* L.	3	17.6	62.5	30.0	36.7	*Pinus taeda* L.	4	17.4	62.6	23.1	34.4
S6797A	*Quercus alba* L.	4	22.2	40.5	37.1	33.3	*Quercus alba* L.	4	21.1	29.2	24.1	24.8
S6797B	*Pinus taeda* L.	3	17.6	51.6	21.9	30.4	*Pinus taeda* L.	3	20.0	63.7	31.8	38.5
S6797C	*Pinus echinata* P. Mill.	4	14.3	36.1	21.6	24.0	*Pinus taeda* L.	3	15.8	31.6	14.7	20.7
S6797D	*Quercus alba* L.	4	22.2	37.4	37.1	32.2	*Quercus alba* L.	4	22.2	41.5	34.3	32.7

MIDSTORY												
1994							2016					
STAND	**SPECIES**	**FREQ**	**RFREQ %**	**RBA %**	**RDEN %**	**IV**	**SPECIES**	**FREQ**	**RFREQ %**	**RBA %**	**RDEN %**	**IV**
A2801A	*Ostrya virginiana* (P. Mill.) K. Koch	3	10.3	13.9	15.2	13.1	*Asimina parviflora* (Michx.) Dunal	3	13.6	25.6	25.6	21.6
A0130	*Nyssa sylvatica* Marsh.	1	25.0	60.2	40.0	41.7	*Nyssa sylvatica Marsh.*	2	66.7	66.7	66.7	66.7
A2025A	*Cornus florida* L.	3	12.0	22.7	23.9	19.5	*Ostrya virginiana* (P. Mill.) K. Koch	4	5.6	18.1	18.4	14.0
A2010A	*Ostrya virginiana* (P. Mill.) K. Koch	4	23.5	34.2	43.1	33.6	*Ilex opaca* Ait.	3	30.0	30.6	21.4	27.4
A2010B	*Symplocos tinctoria* (L.) L'Her.	3	15.0	22.7	38.3	25.3	*Nyssa sylvatica* Marsh.	3	16.7	28.1	30.5	25.1
S6797A	*Acer barbatum* Michx.	3	13.6	24.8	18.6	19.0	*Acer barbatum* Michx.	4	22.2	75.9	42.4	46.8
S6797B	*Asimina triloba* (L.) Dunal	4	11.8	24.9	32.3	23.0	*Acer barbatum* Michx.	3	23.1	33.3	39.1	31.8
S6797C	*Asimina triloba* (L.) Dunal	4	13.8	25.9	43.0	27.5	*Asimina triloba* (L.) Dunal	4	15.4	38.1	46.5	33.3
S6797D	*Asimina triloba* (L.) Dunal	3	27.3	57.5	62.1	49.0	*Asimina triloba* (L.) Dunal	4	30.8	56.4	72.6	53.2

Table 6 - A summary of species indicated as having the highest importance value (IV) in each of the 9 mesic slope ecosystem types identified from 30 upland forest stands in the Angelina and Sabine National Forests, Texas, USA, sampled in 1994/95 and resampled in 2016. Species frequency (FREQ), percent relative frequency (RFREQ%), percent relative basal area (RBA%) and percent relative density (RDEN%) are shown for the overstory and midstory. Species frequency (FREQ), percent relative frequency (RFREQ%), percent relative occurrence (ROC%) and percent relative coverage (RCOV%) are shown for the herbaceous layer.

	1994						2016					
STAND	**SPECIES**	**FREQ**	**RFREQ %**	**ROC %**	**RCOV %**	**IV**	**SPECIES**	**FREQ**	**RFREQ %**	**ROC %**	**RCOV %**	**IV**
A2801A	*Parthenocissus quinquefolia* (L.) Planch.	3	1.6	2.2	11.6	5.2	*Vitis rotundifolia* Michx.	4	4.4	4.8	20.4	9.9
A0130	*Mitchella repens* L.	4	3.7	5.9	27.1	12.2	*Vitis rotundifolia* Michx.	4	3.9	5.3	20.3	9.8
A2025A	*Toxicodendron radicans* (L.) Kuntze	4	2.5	3.6	20.2	8.8	*Mitchella repens* L.	4	2.8	3.4	21.9	9.4
A2010A	*Mitchella repens* L.	4	4.1	6.4	13.7	8.1	*Mitchella repens* L.	4	6.5	9.7	41.3	19.1
A2010B	*Symplocos tinctoria (L.) L'Her.*	4	4.5	6.5	36.9	16.0	*Mitchella repens* L.	4	6.2	9.0	41.7	19.0
S6797A	*Smilax pumila* Walt.	4	3.0	4.6	17.2	8.3	*Smilax pumila* Walt.	4	4.1	5.9	38.3	16.1
S6797B	*Smilax pumila* Walt.	4	1.6	3.3	12.3	5.7	*Smilax pumila* Walt.	4	4.0	6.3	44.4	18.2
S6797C	*Smilax pumila* Walt.	4	2.4	3.8	22.3	9.5	*Vitis rotundifolia* Michx.	4	5.6	8.0	47.9	20.5
S6797D	*Smilax pumila* Walt.	4	3.0	4.6	24.6	10.7	*Smilax pumila* Walt.	4	8.2	12.2	67.4	29.3

Table 7 - A summary of species indicated as having the highest importance value (IV) in each of the 8 dry-mesic ecosystem types identified from 30 upland forest stands in the Angelina and Sabine National Forests, Texas, USA, sampled in 1994/95 and resampled in 2016. Species frequency (FREQ), percent relative frequency (RFREQ%), percent relative basal area (RBA%) and percent relative density (RDEN%) are shown for the overstory and midstory. Species frequency (FREQ), percent relative frequency (RFREQ%), percent relative occurrence (ROC%) and percent relative coverage (RCOV%) are shown for the herbaceous layer. Duplicate entries indicate more than one species having shown a large importance value above all other species in the stand.

OVERSTORY										
	1994					**2016**				
STAND	**SPECIES**	**RFREQ %**	**RBA %**	**RDEN %**	**IV**	**SPECIES**	**RFREQ %**	**RBA %**	**RDEN %**	**IV**
A0624	*Pinus taeda* L.	26.7	83.6	83.1	73.3	*Pinus taeda* L.	40.0	78.2	62.5	60.2
A1113	*Pinus echinata* P. Mill.	28.6	69.1	49.3	49.0	*Pinus echinata* P. Mill.	22.2	53.4	36.2	37.3
A1122	*Pinus echinata* P. Mill.	18.2	80.8	41.7	48.2	*Pinus echinata* P. Mill.	15.4	56.7	23.1	31.7
A1128	*Pinus echinata* P. Mill.	12.0	40.2	21.1	24.4	*Pinus echinata* P. Mill.	15.0	36.3	21.4	24.2
A2610	*Pinus taeda* L.	26.7	57.4	53.8	46.0	*Pinus taeda* L.	25.0	77.3	57.5	53.3
A2801C	*Pinus taeda* L.	13.6	31.9	7.5	17.7	*Pinus echinata* P. Mill.	6.7	39.1	18.2	21.3
A2801D	*Quercus falcata* Michx.	19.0	37.2	30.2	28.8	*Quercus stellata* Wangenh.	18.8	27.7	30.8	25.7
A1407	*Pinus palustris* P. Mill.	28.6	61.0	42.1	43.9	*Pinus taeda* L.	20.0	56.7	41.2	39.3

MIDSTORY										
	1994					**2016**				
STAND	**SPECIES**	**RFREQ %**	**RBA %**	**RDEN %**	**IV**	**SPECIES**	**RFREQ %**	**RBA %**	**RDEN %**	**IV**
A0624	*Ilex vomitoria* Ait.	10.5	16.0	27.3	17.9	*Ilex decidua* Walt.	16.7	73.7	79.1	56.5
A0624	*Quercus marilandica* Muenchh.	10.5	31.1	11.9	17.8	--				
A1113	*Acer rubrum* L.	23.5	33.5	44.7	33.9	*Acer rubrum* L.	21.1	42.9	42.9	35.6
A1122	*Callicarpa americana* L.	23.5	28.5	40.5	30.8	*Callicarpa americana* L.	23.1	54.1	54.1	43.7
A1128	*Liquidambar styraciflua* L.	15.4	18.2	14.2	15.9	*Callicarpa americana* L.	23.5	43.8	43.8	37.0
A1128	*Quercus falcata* Michx.	7.7	21.8	13.1	14.2	--				
A2610	*Ulmus alata* Michx.	10.8	19.6	14.4	15.0	*Ilex vomitoria* Ait.	28.6	50.0	66.0	48.2
A2610	*Fraxinus americana* L.	10.8	15.4	16.7	14.3	--				
A2801C	*Callicarpa americana* L.	18.2	21.5	51.6	30.4	*Callicarpa americana* L.	50.0	70.7	70.7	63.8
A2801D	*Ilex vomitoria* Ait.	16.7	51.5	58.6	42.3	*Ilex vomitoria* Ait.	44.4	84.7	84.7	71.3
A1407	*Liquidambar styraciflua* L.	14.3	41.2	46.4	34.0	*Liquidambar styraciflua* L.	28.6	54.5	54.5	45.8

Table 7 - A summary of species indicated as having the highest importance value (IV) in each of the 8 dry-mesic ecosystem types identified from 30 upland forest stands in the Angelina and Sabine National Forests, Texas, USA, sampled in 1994/95 and resampled in 2016. Species frequency (FREQ), percent relative frequency (RFREQ%), percent relative basal area (RBA%) and percent relative density (RDEN%) are shown for the overstory and midstory. Species frequency (FREQ), percent relative frequency (RFREQ%), percent relative occurrence (ROC%) and percent relative coverage (RCOV%) are shown for the herbaceous layer. Duplicate entries indicate more than one species having shown a large importance value above all other species in the stand.

HERB										
1994						2016				
STAND	**SPECIES**	**RFREQ %**	**ROC %**	**RCOV %**	**IV**	**SPECIES**	**RFREQ %**	**ROC %**	**RCOV %**	**IV**
A0624	*Gelsemium sempervirens* St.-Hil.	2.1	3.6	26.7	10.8	*Chasmanthium sessiliflorum* (Poir.) Yates	4.8	5.9	22.9	11.2
A1113	*Gelsemium sempervirens* St.-Hil.	1.8	3.1	18.4	7.8	*Chasmanthium sessiliflorum* (Poir.) Yates	4.8	7.4	32.1	14.8
A1122	*Toxicodendron radicans* (L.) Kuntze	2.5	3.7	27.7	11.3	*Chasmanthium sessiliflorum* (Poir.) Yates	3.5	5.0	16.7	8.4
A1128	*Chasmanthium sessiliflorum* (Poir.) Yates	1.6	2.7	16.6	7.0	*Vitis rotundifolia* Michx.	2.6	3.2	46.8	17.5
A2610	*Scleria oligantha* Michx.	2.6	4.3	12.0	6.3	*Chasmanthium sessiliflorum* (Poir.) Yates	4.3	6.8	18.3	9.8
A2801C	*Smilax pumila* Walt.	1.2	1.6	26.1	9.6	*Callicarpa americana* L.	4.3	5.7	20.5	10.2
A2801D	*Chasmanthium sessiliflorum* (Poir.) Yates	2.7	4.5	52.7	20.0	*Chasmanthium sessiliflorum* (Poir.) Yates	5.1	7.6	31.9	14.9
A1407	*Callicarpa americana* L.	2.0	2.2	15.5	6.6	*Mitchella repens L.*	3.4	3.2	21.9	9.5

Table 8 –A summary of species indicated as having the highest importance value (IV) in each of the 3 forested seep ecosystem types identified from 30 upland forest stands in the Angelina and Sabine National Forests, Texas, USA, sampled in 1994/95 and resampled in 2016. Species frequency (FREQ), percent relative frequency (RFREQ%), percent relative basal area (RBA%) and percent relative density (RDEN%) are shown for the overstory and midstory. Species frequency (FREQ), percent relative frequency (RFREQ%), percent relative occurrence (ROC%) and percent relative coverage (RCOV%) are shown for the herbaceous layer.

OVERSTORY												
1994							2016					
STAND	**SPECIES**	**FREQ**	**RFREQ %**	**RBA %**	**RDEN %**	**IV**	**SPECIES**	**FREQ**	**RFREQ %**	**RBA %**	**RDEN %**	**IV**
A1490	*Pinus taeda* L.	4	19.0	45.0	19.6	17.3	*Pinus taeda* L.	3	18.8	51.5	30.0	33.4
A1612	*Nyssa sylvatica* Marsh.	4	22.2	39.5	46.5	27.9	*Nyssa sylvatica* Marsh.	4	21.1	30.9	42.9	31.6
A76A	*Magnolia virginiana* L.	4	14.3	14.3	22.9	36.1	*Pinus taeda* L.	2	9.5	34.9	11.4	18.6

MIDSTORY												
1994							2016					
STAND	**SPECIES**	**FREQ**	**RFREQ %**	**RBA %**	**RDEN %**	**IV**	**SPECIES**	**FREQ**	**RFREQ %**	**RBA %**	**RDEN %**	**IV**
A1490	*Acer rubrum* L.	2	15.8	17.8	22.5	18.7	*Sebastiania fruticosa* (Bartr.) Fern.	3	23.1	35.6	30.2	29.6
A1612	*Persea borbonia* (L.) Spreng.	4	15.4	60.7	46.5	40.9	*Morella cerifera* (L.) Small	4	13.3	30.0	41.5	28.3
A76A	*Ilex coriacea* (Pursh) Chapman	4	12.5	13.5	21.6	15.8	*Ilex coriacea* (Pursh) Chapman	4	19.0	71.5	78.8	56.5

HERB												
1994							2016					
STAND	**SPECIES**	**FREQ**	**RFREQ %**	**ROC %**	**RCOV %**	**IV**	**SPECIES**	**FREQ**	**RFREQ %**	**ROC %**	**RCOV %**	**IV**
A1490	*Smilax pumila* Walt.	4	2.9	4.6	28.0	11.8	*Smilax pumila* Walt.	4	4.6	6.6	29.3	13.5
A1612	*Woodwardia areolata* (L.) T. Moore	4	3.3	5.0	33.6	14.0	*Osmunda regalis* L.	4	3.8	4.7	18.6	9.0
A76A	*Rhododendron canescens* (Michx.) Sweet	4	2.8	4.1	17.2	8.0	*Osmunda cinnamomea* L.	4	5.6	7.5	24.6	12.6

iii. Stand Comparisons

Initial comparisons between stands was conducted using basic diversity measures. Species diversity (Shannon Index) for all stands was found to be equal or higher in the 1994/95 sampling period relative to 2016. The highest diversity in 1994/95 occurred in the Dry-mesic ecosystems with the Longleaf pine upland ecosystems being slightly lower. Conversely, the highest diversity in 2016 was found in the Longleaf pine ecosystem and the Mesic slope and stream bottom ecosystem. Two-sample t-tests were conducted for each ecosystem type and for each stratum to determine whether any significant change had occurred between sample years. Table 9 shows that no significant change in diversity occurred in the overstory for all stands. However, the Longleaf pine uplands ($p=0.0434$) and Dry-mesic uplands ($p = 0.0029$) appear to have experienced significant change in species diversity in the midstory while the Dry-mesic uplands and Mesic slope and stream bottom ecosystem types experienced significant change in species diversity in the herbaceous layer ($p = 0.0002$; $p = 0.0058$, respectively).

As set out in Table 10, species evenness in all sample stands appeared to be relatively static in the overstory ($p = 0.4577$). However, two-sample t-tests revealed that species evenness significantly altered between sampling periods in the midstory for the Dry-mesic uplands ($p = 0.0003$) and in the herbaceous layer for the Longleaf pine uplands ($p = 0.0143$).

Species richness was examined from the total of 444 plant species identified between the 1994/95 and 2016 sampling periods. Of the total species identified, 207 remained present in 2016 from the 1994/95 data, 141 species were absent from the 1994/95 data by 2016 and 96 new species were identified in 2016. The overstory consisted of a total of 37 species with 28 being identified in both sampling periods. Four species were absent and five additional species were identified in 2016. Of these five additional species (*Chionanthus virginicus* L., *Ilex coriacea* (Pursh) Chapman, *Juniperus virginiana* L., *Quercus phellos* L. and *Ulmus americana* L.), all but *Ulmus americana L.* were identified in the 1994/95 midstory of their respective stands. *Ulmus americana L.* occurred only once, with a dbh of 12.7-cm, and is likely an addition from an adjacent community. Two-sample t-tests comparing species richness between sample periods indicated no significant difference had occurred in the overstory (Table 11). The midstory comprised 75 species in total. Of these species, 55 were identified in both sampling periods. A total of six species were no longer present from 1994/95 and 14 new species were identified in 2016. Specifically, *Berchemia scandens* (Hill) K. Koch, *Prunus serotina* Ehrh., *Cercis canadensis* L., *Crataegus spathulata* Michx., *Diospyros virginiana* L. and *Toxicodendron vernix* (L.) Kuntze were no longer present in 2016 and, of the 14 new species identified, species such as *Carya ovata* (P. Mill.) K. Koch, *Prunus caroliniana* (P. Mill.) Ait. and *Rhus glabra* L. were among those identified upon resampling of the midstory in 2016. Two-sample t-tests comparing species richness in this stratum indicated that the

Longleaf pine upland ecosystem and the Dry-mesic ecosystem had significantly changed in species richness between the sampling periods ($p = 0.0221$; $p = 0.0050$, respectively). The remaining 332 species of the 444 plant species identified were found in the herbaceous layer of the sampled stands. Two-sample t-tests comparing species richness in this stratum indicated that species richness had altered significantly between sampling periods for the Dry-mesic upland ($p = 0.0001$) and for the Mesic slopes and stream bottoms ($p = 0.0065$) ecosystem types. Species that were not found in the 2016 herbaceous layers include *Asclepias viridiflora* Raf. and *Asclepias tuberosa* L., *Gymnopogon brevifolius* Trin. and *Dichanthelium sphaerocarpon* (Ell.) Gould, *Desmodium paniculatum* (L.) DC., and *Dalea phleoides* (Torr. & Gray) Shinners. The new species identified in the 2016 herbaceous layers varied widely and ranged from *Panicum verrucosum* Muhl., *Panicum dichotomiflorum* Michx. and *Chasmanthium latifolium* (Michx.) Yates, to *Lactuca floridana* (L.) Gaertn. and *Liatris elegans* (Walter) Michx. The general trend between sampling years appears to be a decrease in species richness from 1994/95 to 2016. A complete list of all species identified in each sampling year and each stratum is set out in Tables 12 to 20 in the Appendix. In addition, a detailed summary of Shannon Index and Pielou's evenness Index values for all 30 stands is set out in Tables 21 and 22 in the Appendix.

Relative turnover rates (TR) for species ranged from 0% to 5.95% with both the highest and lowest turnover rates occurring in the overstory and midstory of the

Sandyland ecosystem type, respectively. Although turnover rates appeared superficially to widely vary between ecosystem types for both overstory and midstory strata a comparison of absolute turnover (TA) as well as relative turnover rates by ANOVA indicated that no one ecosystem type experienced significantly higher or lower turnover with respect to the other in the overstory (TA $p = 0.095$; TR $p = 0.712$) or in the midstory (TA $p = 0.108$; $p = 0.677$). Table 11 shows that the herbaceous layer did, however, reflect a significant difference in turnover rates between ecosystem types (TA $p = 0.001$; TR $p = 0.004$). Turnover rates in this stratum ranged from 1.52% to 2.54% with the Mesic slope and stream bottom ecosystem type seemingly having the lowest turnover rates while the Longleaf pine ecosystem type appeared to have the highest. A detailed list of species richness values and turnover rates for all 30 stands for each stratum is set out in Tables 23 to 25 in the Appendix.

Table 9 - Shannon Diversity Index p-values for the 30 upland forest stands from the Angelina and Sabine National Forests, Texas, USA, sampled in 1994/95 and resampled in 2016.

	SHANNON INDEX (H')	
Ecosystem Type	**Stratum**	**p-values**
All	Overstory	0.0700
Longleaf pine	Midstory	0.0434
Dry-mesic	Midstory	0.0029
	Herbaceous	0.0002
Mesic	Herbaceous	0.0058

Table 10 - Pielou's Evenness Index p-values for the 30 upland forest stands from the Angelina and Sabine National Forests, Texas, USA, sampled in 1994/95 and resampled in 2016.

	PIELOUS's EVENNESS (J)	
Ecosystem Type	**Stratum**	**p-values**
All	Overstory	0.4577
Dry-mesic	Midstory	0.0003
Longleaf pine	Herbaceous	0.0143

Table 11 –Species richness and turnover rates (TA – absolute turnover; TR – relative turnover) p-values for the 30 upland forest stands from the Angelina and Sabine National Forests, Texas, USA, sampled in 1994/95 and resampled in 2016.

		SPECIES RICHNESS & TURNOVER		
		Species richness	**Turnover**	
Ecosystem Type	**Stratum**	**p-values**	**TA p-values**	**TR p-values**
All	Overstory	0.2090	0.0950	0.7120
Longleaf pine	Midstory	0.0221	0.1080	0.6774
Dry-mesic	Midstory	0.0050		
Dry-mesic	Herbaceous	0.0001	0.0010	0.0040
mesic	Herbaceous	0.0065		

CHAPTER 5 - DISCUSSION

i. Succession Characteristics

Successional change is observable in several of the ecosystem types examined. However, there was also a measurable change occurring between the different stratum of these ecosystems. The overstory was found to be the most stable, distinguishing this strata as the least impacted by short-term (i.e., 20 year) disturbance factors. Four of the five new species introduced into the overstory by 2016 were present in the midstory of the 1994/95 data and this suggests a strong reliance on the lower strata for recruitment. Speculation on possible overstory changes by looking at the recruitment of these species on an individual case basis was not considered for the purposes of this thesis. The fifth species, *Ulmus americana L.*, likely immigrated from an adjacent community within this period. However, the small diameter (dbh: 12.7-cm) prohibits any substantive discussion of successional trend. Overall the data appears to suggest a maturing of the midstory more than the recruitment of new species into the overstory. That a gradual shift in overstory species may be occurring in each of these stands is shown by the ordinal differences between 1994/95 and 2016 in the Procrustes analysis (Figure 13). Of particular note are the direction and strength of the arrows relating to the Longleaf pine and Sandyland ecosystem types. These larger shifts appear to be a result of increased importance valuesfor *Pinus palustris* P. Mill. (Table 4 and Table 5), which is due in part from the present forest management practice of prescribed burning in these areas.

The midstory and herbaceous strata were both shown to have had the most significant shift in vegetation composition by Procrustes analyses (Figures 14 and 15) and also by statistical analyses. The Longleaf pine uplands, Dry-mesic and Mesic midstory ecosystem types had the highest evidence of a reduction in diversity, indicating that plant communities have not altered equally across ecosystem types. However, the impact to only some of the ecosystem types was not surprising as only some areas appear to be under disturbance pressure. For example, the Longleaf pine uplands areas are experiencing high fire disturbance pressure. The midstory of this ecosystem type appears to have undergone a significant reduction in diversity and the herbaceous layer has had a significant decline in evenness since 1994/95. Similarly, the mesic sites have experienced high hog activity resulting in a significant reduction in species diversity and species richness in the herbaceous layer since 1994/95. Although appearing less impacted by hog activity as of 2016, the significant reduction in species diversity, evenness and richness in the midstory of the Dry-mesic ecosystem is suggestive that the combination of wind disturbance with hog activity may have had a high impact to this ecosystem type. That these disturbance factors are effecting vegetation composition structure in these ecosystem types is consistent with other studies that suggest that forest disturbance can drive compositional changes in the vegetation of forest communities depending on their regularity and severity (Davis, 1981).

It was surprising, however, to arguably find the greatest evidence of change to have occurred in the midstory. Figure 14 shows large directional shifts occurring in several stands. Table 4 suggests the vegetation midstory changes to the Longleaf pine ecosystem may have occurred due in part to the replacement of *Sassafras albidum (Nutt.) Nees* in one stand with *Rhus copallinum* L. (A92B) and a recent invasion of *Ilex vomitoria* Ait. in another (A98C). The Mesic slope and stream bottom ecosystem types tended to drift in the same ordinal direction (Figure 14). This suggests that species composition dynamics are unified across this ecosystem type. That is, the vegetation composition of this ecosystem has become more similar since 1994/95. As shown in Table 6, importance values from 1994/95 have generally increased for the species within these stands (e.g. *Acer barbatum* Michx., S6797A).

Interestingly, the herbaceous layer showed less of a directional shift of the stands in ordination space than the midstory (Figure 15). The Dry-mesic ecosystem type appears to be undergoing a shift in distribution of importance values and this may be more the result from reduced species richness rather than from reduced species diversity. Table 7 illustrates this point as species tend to be similar between sample years, if present at all. A large directional change, indicated by arrow length, was also observed in the herbaceous layer of the mesic slopes and stream bottom stands. Figure 15 shows that S6797B, A2025A and S6797A experienced the largest vegetation shift. Table 6 reflects this change by, for example, the previous importance values of species such as *Toxicodendron radicans* (L.) Kuntze being replaced by species such as *Mitchella repens* L. (A2025A) and *Smilax pumila* Walt. increasing over a hundred-fold in importance value for both A6297A and A6797B. Accordingly, wind disturbance and feral hog disturbance may both be ultimately responsible for this shift in vegetation.

While the Forested Seep ecosystem type appears to have the largest directional shift in the midstory and, particularly, in the herbaceous layers, these changes appear to be more of a reflection of the dynamic properties of this ecosystem type. As set out in Table 8, importance values for species in the midstory differed for A1490 and A1612, but not A76A. Conversely, importance values for A1612 and A76A differed in the herbaceous layer, while A1490 did not. For example, *Woodwardia areolata* (L.) T. Moore importance values have been replaced by *Osmunda regalis* L. in stand A1612 and *Rhododendron canescens* (Michx.) Sweet importance values have been replaced by *Osmunda cinnamomea* L. in A76A. Accordingly, it is difficult from this analysis to determine whether a gradual shift in vegetation composition is occurring or whether this shift reflects some factor affecting this ecosystem type.

Nevertheless, the above results highlight that ecologists interested in functional relationships within and between ecosystem types may consider more detailed analysis of trends by stratum rather than solely by the traditional approach of observing the ecosystem as a whole. This framework will also assist in forming better hypotheses in examining successional trends.

ii. Disturbance Events

The Longleaf pine ecosystem type stands currently undergo routine prescribed burning regimes. Evidence of fire was observed within all of the sample areas of the present study and were identified as having been burned within the last five years. The objective to promote *Pinus palustris* P. Mill. (longleaf pine) in this ecosystem type appears to have been successful as *Pinus palustris* P. Mill. remains the dominant tree in these areas. Typical accompanying tree species, for example, *Quercus incana* Bartr. and *Carya texana* Buckl. are seemlingly uncommon whereas *Quercus stellata* Wangenh. and *Cornus florida* L. are now more common in this ecosystem type. However, as previously set out, the overall changes to the overstory have not been to any significant degree. Important midstory trees have also remained stable in this ecosystem type over the past 20 years. *Quercus marilandica* Muenchh. (oak) and *Rhus copallinum* L. (sumac) are known indicator species of this ecosystem. Nevertheless, t-tests between the sample periods suggest that diversity (Shannon Index) and species richness are significantly reduced ($p = 0.0434$; $p = 0.0220$). As mentioned previously, this finding was unsurprising since fire disturbance is a large determinant of vegetation shift as it affects many aspects of the community including soil and competition dynamics (Silva, et al., 2013). It's important to note that the degree of change in diversity in this ecosystem type is circumspect since the degree of significance is closely proximate the alpha level ($\alpha = 0.05$). Antithetically, a clear significant reduction in species evenness was identified in the herbaceous layer ($p = 0.0143$). And, it has been suggested in the literature that reduced evenness is a *priori* indicator of biodiversity loss prior to extinction of plant species (Hillebrand, et al., 2008). As regular burning effects can restrain the species pool (Silva, et al., 2013) there is likely a reduction in diversity in this stand due to current disturbance factors and the significance of the change in this ecosystem type appears to be correctly interpreted.

A major shift in community dynamics also occurred in the midstory of the Dry-mesic ecosystem type. Field observations indicate these sites tend to be comprised of dense midstory levels with a number of fallen overstory trees, some stands having open canopies. The important overstory indicators include *Pinus taeda* L. and *Liquidambar styraciflua* L., which are typical associates in the eastern Texas forest (Van Kley, 2007). However, *Pinus taeda* L. and *Pinus echinata* P. Mill. were identified as the dominant species in the overstory for this ecosystem type in 1994/95 and in 2016. In the midstory, *Ilex vomitoria* Ait., *Liquidambar styraciflua* L. and *Callicarpa Americana* L. were historically important species but *Ilex decidua* Walt., *Ilex vomitoria* Ait. and *Callicarpa Americana* L. had high importance values by 2016 (Table 7). The replacement of *Liquidambar styraciflua* L. may imply a change in hydrologic and/or soil surface properties impacting this area (Baker and Langdon, 1990) as *Liquidambar styraciflua* L. is a generally less shade tolerant species that was expected to remain present in the 2016 sampling period. Paired t-tests comparing midstory diversity and evenness temporally were both found to be significant ($p = 0.0029$; $p = 0.0003$). Species diversity was also identified by two-sample t-tests to be significantly reduced in the herbaceous layer ($p = 0.0002$). Moreover, both midstory and herbaceous layers were found to have significantly declining species richness ($p = 0.0050$; 0.0001). *Ilex decidua* Walt. tends to proliferate in large dense clumps, limiting access to sun and nutrients, which may have resulted in the low species counts of herbaceous species in some sample sites. Figures 10, 11 and 12 show that some hog activity occurred in this area but that fire and wind disturbance were strong factors in this ecosystem. While wind disturbance appears to likely be a large contributor, it is unclear whether it is the combination of fire and disturbance from windthrow or one particular factor that has contributed to the shift in vegetation diversity in these stands.

The Mesic slope and stream bottom ecosystem types were also found to have been significantly impacted over the past 20 years. Hogs typically prefer mesic sites and bottomlands (Chavarria, et al., 2007) and based on the ordination results of 2016 for this ecosystem type hog activity has been a major disturbance factor in these stands. Hog activity has been shown to affect forest soil carbon in temperate forests (Wirthner, et al., 2012). However, as of this writing, the author has no knowledge of studies relating to effects in subtropical forests. The midstory species originally comprised *Cornus florida* L., *Acer rubrum* L., *Fraxinus Americana* L. and *Liquidamber styraciflua* L. in 1994/95. Midstory taxa has transitioned to include *Chionanthus virginicus* L., *Ostrya virginiana* (P. Mill.) K. Koch, *Fagus grandifolia* Ehrh. and *Carpinus carolineana* Walt. Statistical analyses did not show any significant differences in diversity or evenness in the midstory. However, a significant reduction in species richness and diversity was noted in the herbaceous layer ($p = 0.0065$; $p = 0.0058$). The overall trend for the decline in species richness and diversity appears to be related to hog activity and windthrow disturbances. Hog activity was high in two of the nine stands while evidence of windthrow was found in all but one of these stands. Of note, is that stand A1490 is now more firmly positioned in ordinal space with the Mesic ecosystem type whereas in 1994/95 it was more indicative of the Forested seep ecosystem type. This stand appears to have been affected by multiple disturbance factors in a similar manner to the mesic stands. The vegetation community shift of this stand to a more definitive Mesic ecosystem type, therefore, may be tied to the dynamic properties of the forested seep when undergoing similar disturbance factors.

Of particular note from field observations during this study was that invasive species were either not found or were found in very small numbers. An invasive species is a plant that is a non-native to the ecosystem under consideration and whose introduction causes or is likely to cause harm to the local flora by, for example, outcompeting the local species. *Triadica sebifera* (L.) Small is a known invasive species in east Texas which has increased in population in the area in recent years due to anthropogenic activities (Montez, 2016). Accordingly, the lack of this species in these stands is likely due in part to their location. These stands are distanced away from urban centers and are typically under less pressure from anthropogenic activities. Moreover, none of these stands are categorized as a bottomland ecosystem types in which *Triadica sebifera* (L.) Small is currently found. Conversely, *Ligustrum sinense* Lour. was identified in one stand in the Forested seep ecosystem type. This species was found in the herbaceous layer of stand A1612, having an importance value of 0.6. This species is known to aggressively outcompete local flora. Accordingly, future studies that may identify a decrease in native species richness and species evenness in this stand may be attributable to this initial introduction.

All remaining stands and/or ecosystem types did not show any significant differences in diversity, species richness or species evenness due to disturbance events.

iii. Extreme Disturbance Events

The composition and structure of vegetation communities are expected to be altered from extreme disturbance events (Ge, et al., 2013). However, if the sample stands of this study were subject to effects from Hurricane Rita or Hurricane Ike, such effects were not readily observable. A study conducted shortly after Hurricane Rita, in a region south of the present study area, noted that a shift in vegetation had occurred in the midstory (small tree layers) of both dry and mesic sites but had resulted in minimal damage (Harcombe, et al., 2009). As more severe damage would have occurred to the south of these stands, it is, therefore, reasonable to infer that any damage that may have occurred from Hurricane Rita or Hurricane Ike would be imperceptible by 2016.

Field observations and a reduction of basal area for *Cornus florida* L. (Betulaceae) suggests that this species has significantly reduced in number since sampling in 1994/95. Table 6 shows that *Cornus florida* L. once was of high importance value for Mesic slopes and creek bottom ecosystem types. However, this species is no longer of high importance in any of the ecosystems under study. It has been suggested that the decline of *Cornus florida* L., at least in the bottomlands of east Texas, is due to this species' intolerance to flooding (Mann, et al., 2008). However, Mann's study noted that a drought had also occurred prior to the reduction of *Cornus florida* L. Accordingly, it may be that the drought of 2011 may have contributed to *Cornus florida* L. mortality.

iv. Turnover Rates

Relative and absolute turnover rates for each stand was calculated in accord with the methods of Chepinoga, et al. (2012). Due to the unevenness of the sampled ecosystems, only a limited analysis was possible. The results of the analysis suggest that there were no significant differences in turnover or absolute turnover rates in the overstory or midstory for any of the ecosystem types under study (Figures 23 and 24). However, the herbaceous layer showed a significant difference in relative turnover and absolute turnover ($p = 0.001$; $p = 0.004$) between the sample periods (Figure 25). Not surprisingly, these results imply that herbaceous turnover was more rapid than midstory and overstory regardless of disturbance.

The current emphasis in this study of plant communities and their response to disturbance events has shown that different disturbance events may impact vegetation communities in specific ecosystem types. Although historically communities often have been identified as poor tools for specific target purposes, e.g. predicting future communities (Palik, et al., 2000), available systematic descriptions of terrestrial plant cover is an obvious metric for the assessment of vegetation dynamics.

CHAPTER 6 - CONCLUSION

Comparison of the forested stands in each of the five ecosystem types of this study was successful in showing vegetation change occurred in the Angelina and Sabine National Forests of east Texas. Vegetation composition changes differed not only between the different ecosystem types but also within the vertical organization of each ecosystem type. While the search for general principles governing succession remains unclear (Baasch, et al., 2009), this study illuminates that compositional change in communities is an unequal process across ecosystem types and is subject to varying ecological drivers in short periods of time. In conclusion, this research identified three key results: 1) vegetation composition change occurred more dramatically in Longleaf pine, Dry-mesic and Mesic ecosystem types; 2) that vegetation composition change can vary within different organizational levels of an ecosystem; and, 3) that long-term studies of these areas will emphasize species-time-area relationships that can effectively link vegetation composition to disturbance drivers.

The style guide for the presentation is based on the requirements as set out by Stephen F. Austin State University Thesis Guidelines in the Graduate Bulletin.

CHAPTER 7 - REFERENCES

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CHAPTER 8 – APPENDIX

Table 12 - Ground Species identified in 1994/95 & 2016 with codes from the U.S. Department of Agriculture Plant database, common name and family

CODE	SPECIES	COMMON NAME	FAMILY
ACBA3	*Acer barbatum Michx.*	Florida maple	Aceraceae
ACRU	*Acer rubrum L.*	red maple	Aceraceae
AEPA	*Aesculus pavia L.*	red buckeye	Hippocastanaceae
ALCA3	*Allium canadense L.*	meadow garlic	Liliaceae
AMAR2	*Ambrosia artemisiifolia L.*	common ragwood	Asteraceae
AMPS	*Ambrosia psilostachya DC.*	cuman ragweed	Asteraceae
AMAR5	*Ampelopsis arborea (L.) Koehne*	peppervine	Vitaceae
ANTE2	*Andropogon ternarius Michx.*	splitbeard bluestem	Poaceae
ANVI2	*Andropogon virginicus L.*	broomsedge bluestem	Poaceae
APAP	*Apteria aphylla (Nutt.) Barnh. ex Small*	nodding nixie	Burmanniaceae
ARSP2	*Aralia spinosa L.*	Devil's walkingstick	Araliaceae
ARIST2	*Aristida L.*	Dutchman's pipe	Poaceae
ARRE3	*Aristolochia reticulata Jacq.*	Texas Dutchman's pipe	Aristolochiaceae
ARSE3	*Aristolochia serpentaria L.*	Virginia snakeroot	Aristolochiaceae
ARGI	*Arundinaria gigantea (Walt.) Muhl.*	giant cane	Poaceae
ASVA	*Asclepias variegata L.*	redring milkweed	Asclepiadaceae
ASPA18	*Asimina parviflora (Michx.) Dunal*	smallflower pawpaw	Annonaceae
ASTR	*Asimina triloba (L.) Dunal*	common pawpaw	Annonaceae
ATFI	*Athyrium filix-femina (L.) Roth*	common ladyfern	Dryopteridaceae
AUPE	*Aureolaria pectinata (Nutt.) Pennell*	combleaf yellow false foxglove	Scrophulariaceae
BANU2	*Baptisia nuttalliana Small*	Nuttall's wild indigo	Fabaceae

CODE	SPECIES	COMMON NAME	FAMILY
BESC	*Berchemia scandens (Hill) K. Koch*	Alabama supplejack	Rhamnaceae
BEPU2	*Berlandiera pumila (Michx.) Nutt.*	soft greeneyes	Asteraceae
BINU2	*Bigelowia nuttallii L.C. Anders.*	Nuttall's rayless goldenrod	Asteraceae
BICA	*Bignonia capreolata L.*	crossvine	Bignoniaceae
BOCY	*Boehmeria cylindrica (L.) Sw.*	smallspike false nettle	Urticaceae
CAAM2	*Callicarpa americana L.*	American beautyberry	Verbenaceae
CAPA2	*Callirhoe papaver (Cav.) Gray*	woodland poppymallow	Malvaceae
CARA2	*Campsis radicans (L.) Seem. ex Bureau*	trumpet creeper	Bignoniaceae
CADI5	*Carex digitalis Willd.*	slender woodland sedge	Cyperaceae
CAFO6	*Carex folliculata L.*	littlebag sedge	Cyperaceae
CALE10	*Carex leptalea Wahlenb.*	bristlystalked sedge	Cyperaceae
CAST17	*Carex striatula Michx.*	lined sedge	Cyperaceae
CACA18	*Carpinus caroliniana Walt.*	American hornbeam	Betulaceae
CAAL27	*Carya alba (L.) Nutt. ex Ell.*	mockernut hickory	Juglandaceae
CACO15	*Carya cordiformis (Wangenh.) K. Koch*	bitternut hickory	Juglandaceae
CATE9	*Carya texana Buckl.*	black hickory	Juglandaceae
CAPU9	*Castanea pumila (L.) P. Mill.*	Allegheny chinkapin	Fagaceae
CEAM	*Ceanothus americanus L.*	New Jersey tea	Rhamnaceae
CELA	*Celtis laevigata Willd.*	sugarberry	Ulmaceae
CEVI2	*Centrosema virginianum (L.) Benth.*	spurred butterfly pea	Fabaceae
CECA4	*Cercis canadensis L.*	Eastern redbud	Fabaceae
CHCO11	*Chamaesyce cordifolia (Ell.) Small*	heartleaf sandmat	Euphorbiaceae
CHLA6	*Chasmanthium laxum (L.) Yates*	slender woodoats	Poaceae

CODE	SPECIES	COMMON NAME	FAMILY
CHSE2	*Chasmanthium sessiliflorum (Poir.) Yates*	sessile flowered chasmanthium	Poaceae
CHVI3	*Chionanthus virginicus L.*	white fringetree	Oleaceae
CHPI8	*Chrysopsis pilosa Nutt.*	soft goldenaster	Asteraceae
CICA7	*Cirsium carolinianum (Walt.) Fern. & Schub.*	soft thistle	Asteraceae
CLRE	*Clematis reticulata Walt.*	netleaf leather flower	Ranunculaceae
CNTE	*Cnidoscolus texanus (Muell.-Arg.) Small*	Texas bullnettle	Euphorbiaceae
COER	*Commelina erecta L.*	whitemouth dayflower	Commelinaceae
COFL2	*Cornus florida L.*	flowering dogwood	Cornaceae
CRDI17	*Croptilon divaricatum (Nutt.) Raf.*	slender scratchdaisy	Asteraceae
CRAR2	*Croton argyranthemus Michx.*	healing croton	Euphorbiaceae
CYHY	*Cyperus hystricinus Fern.*	bristly flatsedge	Cyperaceae
CYPL3	*Cyperus plukenetii Fern.*	Plukenet's flatsedge	Cyperaceae
DECA8	*Desmodium canescens (L.) DC.*	hoary ticktrefoil	Fabaceae
DECI	*Desmodium ciliare (Muhl. ex Willd.) DC.*	hairy smallleaf ticktrefoil	Fabaceae
DENU4	*Desmodium nudiflorum (L.) DC.*	nakedflower ticktrefoil	Fabaceae
DERO3	*Desmodium rotundifolium DC.*	prostrate ticktrefoil	Fabaceae
DIAC	*Dichanthelium aciculare (Desv. ex Poir.) Gould & C.A. Clark*	needleleaf rosette grass	Poaceae
DIAC2	*Dichanthelium acuminatum (Sw.) Gould & C.A. Clark*	tapered rosette grass	Poaceae
DICO2	*Dichanthelium commutatum (J.A. Schultes) Gould*	variable panicgrass	Poaceae
DIDI6	*Dichanthelium dichotomum (L.) Gould*	Cypress panicgrass	Poaceae

CODE	SPECIES	COMMON NAME	FAMILY
DITE2	*Diodia teres Walt.*	poorjoe	Rubiaceae
DIQU	*Dioscorea quaternata J.F. Gmel.*	fourleaf yam	Dioscoreaceae
DIVI4	*Dioscorea villosa L.*	wild yam	Dioscoreaceae
ELTO2	*Elephantopus tomentosus L.*	Devil's grandmother	Asteraceae
ERLO5	*Eriogonum longifolium Nutt.*	longleaf buckwheat	Polygonaceae
ERHE4	*Erythrina herbacea L.*	redcardinal	Fabaceae
EUAM7	*Euonymus americana L.*	American strawberrybush	Celastraceae
EUCA5	*Eupatorium capillifolium (Lam.) Small*	dogfennel	Asteraceae
EUPE3	*Eupatorium perfoliatum L.*	common boneset	Asteraceae
EUCO10	*Euphorbia corollata L.*	flowering spurge	Euphorbiaceae
FAGR	*Fagus grandifolia Ehrh.*	American beech	Fagaceae
FOLI	*Forestiera ligustrina (Michx.) Poir.*	upland swampprivet	Oleaceae
FRCA13	*Frangula caroliniana (Walt.) Gray*	Carolina buckthorn	Rhamnaceae
FRAM2	*Fraxinus americana L.*	white ash	Oleaceae
FRFL	*Froelichia floridana (Nutt.) Moq.*	plains snakecotton	Amaranthaceae
GAAE	*Gaillardia aestivalis (Walt.) H. Rock*	lanceleaf blanketflower	Asteraceae
GARE2	*Galactia regularis (L.) B.S.P.*	eastern milkpea	Fabaceae
GESE	*Gelsemium sempervirens St.-Hil.*	evening trumpetflower	Loganiaceae
GYAM	*Gymnopogon ambiguus (Michx.) B.S.P.*	bearded skeletongrass	Poaceae
HAVI4	*Hamamelis virginiana L.*	American witchhazel	Hamamelidaceae
HECA4	*Helianthemum carolinianum (Walt.) Michx.*	Carolina frostweed	Cistaceae
HEAN2	*Helianthus angustifolius L.*	swamp sunflower	Asteraceae
HEHI2	*Helianthus hirsutus Raf.*	hairy sunflower	Asteraceae
HIGR3	*Hieracium gronovii L.*	queendevil	Asteraceae

CODE	SPECIES	COMMON NAME	FAMILY
HYHY	*Hypericum hypericoides (L.) Crantz*	St. Andrews cross	Clusiaceae
ILCO	*Ilex coriacea (Pursh) Chapman*	large gallberry	Aquifoliaceae
ILDE	*Ilex decidua Walt.*	possumhaw	Aquifoliaceae
ILOP	*Ilex opaca Ait.*	American holly	Aquifoliaceae
ILVO	*Ilex vomitoria Ait.*	yaupon	Aquifoliaceae
JUVI	*Juniperus virginiana L.*	eastern redcedar	Cupressaceae
LALU	*Lactuca ludoviciana (Nutt.) Riddell*	biannual lettuce	Asteraceae
LEVI2	*Leersia Sw.*	cutgrass	Poaceae
LEHI2	*Lespedeza hirta (L.) Hornem.*	hairy lespedeza	Fabaceae
LERE2	*Lespedeza repens (L.) W. Bart.*	creeping lespedeza	Fabaceae
LEVI6	*Lespedeza violacea (L.) Pers.*	violet lespedeza	Fabaceae
LIAC	*Liatris acidota Engelm. & Gray*	sharp gayfeather	Asteraceae
LITE	*Liatris tenuis Shinners*	gulf gayfeather	Asteraceae
LIST2	*Liquidambar styraciflua L.*	sweetgum	Hamamelidaceae
LICA13	*Lithospermum caroliniense (Walt. ex J.F. Gmel.) MacM.*	hairy puccoon	Boraginaceae
LOAP	*Lobelia appendiculata A. DC.*	pale lobelia	Campanulaceae
LOSE	*Lonicera sempervirens L.*	trumpet honeysuckle	Caprifoliaceae
MAGR4	*Magnolia grandiflora L.*	southern magnolia	Magnoliaceae
MINU6	*Mimosa nuttallii (DC. ex Britton & Rose) B.L. Turner*	Nuttall's sensitive-briar	Fabaceae
MIRE	*Mitchella repens L.*	partridgeberry	Rubiaceae
MYHE	*Morella caroliniensis (P.Mill.) Small*	evergreen bayberry	Myricaceae
MYCE	*Morella cerifera (L.) Small*	southern bayberry	Myricaceae
MORU2	*Morus rubra L.*	red mulberry	Moraceae
NYSY	*Nyssa sylvatica Marsh.*	blackgum	Nyssaceae
OPST2	*Opuntia stricta (Haw.) Haw.*	erect pricklypear	Cactaceae

CODE	SPECIES	COMMON NAME	FAMILY
OSCI	*Osmunda cinnamomea L.*	cinnamon fern	Osmundaceae
OSRE	*Osmunda regalis L.*	royal fern	Osmundaceae
OSVI	*Ostrya virginiana (P. Mill.) K. Koch*	eastern hophornbeam	Betulaceae
OXST	*Oxalis stricta L.*	common yellow oxalis	Oxalidaceae
PAVI2	*Panicum virgatum L.*	switchgrass	Poaceae
PAQU2	*Parthenocissus quinquefolia (L.) Planch.*	virginia creeper	Vitaceae
PANO2	*Paspalum notatum Fluegge*	bahiagrass	Poaceae
PALU2	*Passiflora lutea L.*	yellow passionflower	Passifloraceae
PEBO	*Persea borbonia (L.) Spreng.*	redbay	Lauraceae
PHLE5	*Phryma leptostachya L.*	American lopseed	Verbenaceae
PHPU7	*Physalis pubescens L.*	husk tomato	Solanaceae
PIEC2	*Pinus echinata P. Mill.*	shortleaf pine	Pinaceae
PIPA2	*Pinus palustris P. Mill.*	longleaf pine	Pinaceae
PITA	*Pinus taeda L.*	loblolly pine	Pinaceae
PIGR4	*Pityopsis graminifolia (Michx.) Nutt.*	narrowleaf silkgrass	Asteraceae
PLPO2	*Pleopeltis polypodioides (L.) Andrews & Windham*	resurrection fern	Polypodiaceae
POPE	*Podophyllum peltatum L.*	mayapple	Berberidaceae
POPO2	*Polygonella polygama (Vent.) Engelm. & Gray*	October flower	Polygonaceae
POAC4	*Polystichum acrostichoides (Michx.) Schott*	Christmas fern	Dryopteridaceae
PRCA	*Prunus caroliniana (P. Mill.) Ait.*	Carolina laurelcherry	Rosaceae
PRSE2	*Prunus serotina Ehrh.*	black cherry	Rosaceae
PTAQ	*Pteridium aquilinum (L.) Kuhn*	western brackenfern	Dennstaedtiaceae
PYTE	*Pycnanthemum tenuifolium Schrad.*	narrowleaf mountainmint	Lamiaceae
QUAL	*Quercus alba L.*	white oak	Fagaceae
QUFA	*Quercus falcata Michx.*	southern red oak	Fagaceae

CODE	SPECIES	COMMON NAME	FAMILY
QUIN	*Quercus incana Bartr.*	bluejack oak	Fagaceae
QULA3	*Quercus laurifolia Michx.*	laurel oak	Fagaceae
QUMA3	*Quercus marilandica Muenchh.*	blackjack oak	Fagaceae
QUNI	*Quercus nigra L.*	water oak	Fagaceae
QUPH	*Quercus phellos L.*	willow oak	Fagaceae
QUST	*Quercus stellata Wangenh.*	post oak	Fagaceae
RHPR	*Rhododendron prinophyllum (Small) Millais*	early azalea	Ericaceae
RHAR4	*Rhus aromatica Ait.*	fragrant sumac	Anacardiaceae
RHCO	*Rhus copallinum L.*	flameleaf sumac	Anacardiaceae
RHRE	*Rhynchosia reniformis DC.*	dollarleaf	Fabaceae
RHMI9	*Rhynchospora mixta Britt.*	mingled beaksedge	Cyperaceae
RUAR2	*Rubus argutus Link*	sawtooth blackberry	Rosaceae
RUFL	*Rubus flagellaris Willd.*	northern dewberry	Rosaceae
RUHI2	*Rudbeckia hirta L.*	blackeyed Susan	Asteraceae
RUCA4	*Ruellia caroliniensis (J.F. Gmel.) Steud.*	Carolina wild petunia	Acanthaceae
RUHU	*Ruellia humilis Nutt.*	fringeleaf wild petunia	Acanthaceae
RUPE4	*Ruellia pedunculata Torr. ex Gray*	stalked wild petunia	Acanthaceae
SAMI8	*Sabal minor (Jacq.) Pers.*	dwarf palmetto	Arecaceae
SACA15	*Sanicula canadensis L.*	Canadian blacksnakeroot	Apiaceae
SAAL5	*Sassafras albidum (Nutt.) Nees*	sassafras	Lauraceae
SCSC	*Schizachyrium scoparium (Michx.) Nash*	little bluestem	Poaceae
SCCI	*Scleria ciliata Michx.*	fringed nutrush	Cyperaceae
SCOL2	*Scleria oligantha Michx.*	littlehead nutrush	Cyperaceae
SCCA4	*Scutellaria cardiophylla Engelm. & Gray*	gulf skullcap	Lamiaceae
SCIN2	*Scutellaria integrifolia L.*	helmet flower	Lamiaceae

CODE	SPECIES	COMMON NAME	FAMILY
SEFR	*Sebastiania fruticosa (Bartr.) Fern.*	gulf sebastiana	Euphorbiaceae
SEAR	*Selaginella arenicola Underwood*	sand spikemoss	Selaginellaceae
SILA20	*Sideroxylon lanuginosum Michx.*	gum bully (Chittimwood)	Sapotaceae
SMBO2	*Smilax bona-nox L.*	saw greenbrier	Smilacaceae
SMGL	*Smilax glauca Walt.*	cat greenbrier	Smilacaceae
SMLA	*Smilax laurifolia L.*	laurel greenbrier	Smilacaceae
SMPU	*Smilax pumila Walt.*	sarsparilla vine	Smilacaceae
SMRO	*Smilax rotundifolia L.*	roundleaf greenbrier	Smilacaceae
SMSM	*Smilax smallii Morong*	lanceleaf greenbrier	Smilacaceae
SOCA6	*Solidago altissima L.*	Canada goldenrod	Asteraceae
SOOD	*Solidago odora Ait.*	anisescented goldenrod	Asteraceae
SPHAG2	*Sphagnum L.*	sphagnum	Sphagnaceae
STSY	*Stillingia sylvatica Garden ex L.*	queensdelight	Euphorbiaceae
STPI3	*Stylisma pickeringii (Torr. ex M.A. Curtis) Gray*	pickering's dawnflower	Convolvulaceae
STBI2	*Stylosanthes biflora (L.) B.S.P.*	sidebeak pencilflower	Fabaceae
STAM4	*Styrax americanus Lam.*	American snowbell	Styracaceae
SYLA4	*Symphyotrichum lateriflorum (L.) Á. Löve & D.*	calico aster	Asteraceae
SYTI	*Symplocos tinctoria (L.) L'Her.*	common sweetleaf	Symplocaceae
TEON	*Tephrosia onobrychoides Nutt.*	multibloom hoarypea	Fabaceae
TEVI	*Tephrosia virginiana (L.) Pers.*	Virginia tephrosia	Fabaceae
TIAM	*Tilia americana L.*	American basswood	Tiliaceae
TIDI	*Tipularia discolor (Pursh) Nutt.*	crippled cranefly	Orchidaceae

CODE	SPECIES	COMMON NAME	FAMILY
TORA2	*Toxicodendron radicans (L.) Kuntze*	eastern poison ivy	Anacardiaceae
TRDI	*Trachelospermum difforme (Walt.) Gray*	climbing dogbane	Apocynaceae
TRHI	*Tradescantia hirsutiflora Bush*	hairyflower spiderwort	Commelinaceae
TRSM	*Tragia smallii Shinners*	small's noseburn	Euphorbiaceae
TRUR	*Tragia urens L.*	wavyleaf noseburn	Euphorbiaceae
TRUR2	*Tragia urticifolia Michx.*	nettleleaf noseburn	Euphorbiaceae
SASE5	*Triadica sebifera (L.) Small*	Chinese tallowtree	Euphorbiaceae
TRTE3	*Trillium texanum Buckley*	Texas wakerobin	Liliaceae
ULAL	*Ulmus alata Michx.*	winged elm	Ulmaceae
VAAR	*Vaccinium arboreum Marsh.*	farkleberry	Ericaceae
VAEL	*Vaccinium elliottii Chapman*	Elliott's blueberry	Ericaceae
VAFU	*Vaccinium fuscatum Ait.*	black highbush blueberry	Ericaceae
VAST	*Vaccinium stamineum L.*	deerberry	Ericaceae
VETE3	*Vernonia texana (Gray) Small*	Texas ironweed	Asteraceae
VIAC	*Viburnum acerifolium L.*	mapleleaf viburnum	Caprifoliaceae
VINU	*Viburnum nudum L.*	possumhaw	Caprifoliaceae
VIRU	*Viburnum rufidulum Raf.*	rusty blackhaw	Caprifoliaceae
VIWA	*Viola walteri House*	prostrate blue violet	Violaceae
VIRO3	*Vitis rotundifolia Michx.*	muscadine	Vitaceae
VIAEA2	*Vitis aestivalis Michx.*	summer grape	
WOAR	*Woodwardia areolata (L.) T. Moore*	netted chainfern	Blechnaceae
YULO	*Yucca louisianensis Trel.*	gulf coast yucca	Agavaceae

Table 13 - Ground species identified in 1994/95 with codes from the U.S. Department of Agriculture Plant database, common name and family

CODE	SPECIES	COMMON NAME	FAMILY
AGPL2	*Agrimonia microcarpa Wallr*	slender agrimony	Rosaceae
ALJU	*Albizia julibrissin Durz.*	silktree	Fabaceae
ALDR2	*Alophia drummondii (Graham) R.C. Foster*	propeller flower	Iridaceae
AMCA6	*Amorpha canescens Pursh*	lead plant	Fabaceae
ANGE	*Andropogon gerardii Vitman*	big bluestem	Poaceae
ANPLA	*Antennaria plantaginifolia (L.) Richards*	pussytoes	Asteraceae
ARDR3	*Arisaema dracontium (L.) Schott*	greendragon	Araceae
ARTR	*Arisaema triphyllum (L.) Schott*	Jack in the pulpit	Araceae
ARTO3	*Aristolochia tomentosa Sims*	woolly dutchman's pipe	Aristolochiaceae
ASOB	*Asclepias obovata Ell.*	pineland milkweed	Asclepiadaceae
ASTU	*Asclepias tuberosa L.*	butterfly milkweed	Asclepiadaceae
ASVE	*Asclepias verticillata L.*	whorled milkweed	Asclepiadaceae
ASVI	*Asclepias viridiflora Raf.*	green milkweed	Asclepiadaceae
AUGR	*Aureolaria grandiflora (Benth.) Pennell*	largeflower yellow false foxglove	Scrophulariaceae
BODI	*Boltonia diffusa Ell.*	Smallhead doll's daisy	Asteraceae
BOVI	*Botrychium virginianum (L.) Sw.*	rattlesnake fern	Ophioglossaceae
BRER2	*Brachyelytrum erectum (Schreb. ex Spreng.) Beauv.*	bearded shorthusk	Poaceae
CACO9	*Carex complanata Torr. & Hook.*	blue sedge	Cyperaceae
CADE5	*Carex debilis Michx.*	white edge sedge	Cyperaceae
CAIN12	*Carex intumescens Rudge*	greater bladder sedge	Cyperaceae
CARE17	*Carex reniformis (Bailey) Small*	kidneyshape sedge	Cyperaceae

CODE	SPECIES	COMMON NAME	FAMILY
CAAL10	*Castanea alnifolia Nutt.*	trailing chinkapin	Fagaceae
CHFA2	*Chamaecrista fasciculata (Michx.) Greene*	sleepingplant	Fabaceae
CLMA	*Cladium mariscoides (Muhl.) Torr.*	smooth sawgrass	Cyperaceae
CLAL3	*Clethra alnifolia L.*	coastal sweetpepperbush	Clethraceae
COCA	*Cocculus carolinus (L.) DC.*	Carolina coralbead	Menispermaceae
COFO	*Cornus foemina P. Mill.*	stiff dogwood	Cornaceae
CORA6	*Cornus racemosa Lam.*	gray dogwood	Cornaceae
CRBR	*Crataegus brachyacantha Sarg. & Engelm.*	blueberry hawthorn	Rosaceae
CRCR2	*Crataegus crus-galli L.*	cockspur hawthorn	Rosaceae
CRSP	*Crataegus spathulata Michx.*	littlehip hawthorn	Rosaceae
CRTE2	*Crataegus texana Buckl.*	Texas hawthorn	Rosaceae
CRUN	*Crataegus uniflora Muenchh.*	dwarf hawthorn	Rosaceae
CRSA4	*Crotalaria sagittalis L.*	arrowhead rattlebox	Fabaceae
CYVI	*Cynoglossum virginianum L.*	wild comfrey	Boraginaceae
CYPS	*Cyperus pseudovegetus Steud.*	marsh flatsedge	Cyperaceae
DAPH2	*Dalea phleoides (Torr. & Gray) Shinners*	slimspike prairieclover	Fabaceae
DECA3	*Delphinium carolinianum Walt.*	Carolina larkspur	Ranunculaceae
DEPA6	*Desmodium paniculatum (L.) DC.*	panicledleaf ticktrefoil	Fabaceae
DEPA7	*Desmodium pauciflorum (Nutt.) DC.*	fewflower ticktrefoil	Fabaceae
DESE	*Desmodium sessilifolium (Torr.) Torr. & Gray*	sessileleaf ticktrefoil	Fabaceae
DILI2	*Dichanthelium linearifolium (Scribn. ex Nash) Gould*	slimleaf panicum	Poaceae
DIOL	*Dichanthelium oligosanthes (J.A.*	Heller's rosette grass	Poaceae

CODE	SPECIES	COMMON NAME	FAMILY
	Schultes) Gould		
DIRA	*Dichanthelium ravenelii (Scribn. & Merr.) Gould*	Ravenel's rosette grass	Poaceae
DISC3	*Dichanthelium scoparium (Lam.) Gould*	velvet panicum	Poaceae
DISP2	*Dichanthelium sphaerocarpon (Ell.) Gould*	roundseed panicum	Poaceae
DIVI5	*Diospyros virginiana L.*	common persimmon	Ebenaceae
ECPA	*Echinacea pallida (Nutt.) Nutt.*	pale purple coneflower	Asteraceae
ERRE	*Eragrostis refracta (Muhl.) Scribn.*	coastal lovegrass	Poaceae
ERAGR	*Eragrostis von Wolf*	lovegrass	Poaceae
ERST3	*Erigeron strigosus Muhl. ex Willd.*	prairie fleabane	Asteraceae
ERYU	*Eryngium yuccifolium Michx.*	button eryngo	Apiaceae
EUFI	*Eupatorium fistulosum Barratt*	trumpetweed	Asteraceae
EULA7	*Eupatorium lancifolium (Torr. & Gray) Small*	lanceleaf thoroughwort	Asteraceae
EURO4	*Eupatorium rotundifolium L.*	roundleaf thoroughwort	Asteraceae
EUSE	*Eupatorium semiserratum DC.*	smallflower thoroughwort	Asteraceae
FIAU2	*Fimbristylis autumnalis (L.) Roemer & J.A. Schultes*	slender fimbry	Cyperaceae
FRPE	*Fraxinus pennsylvanica Marsh.*	green ash	Oleaceae
GAVO	*Galactia volubilis (L.) Britt.*	downy milkpea	Fabaceae
GACI2	*Galium circaezans Michx.*	licorice bedstraw	Rubiaceae
GAOB	*Galium obtusum Bigelow*	bluntleaf bedstraw	Rubiaceae
GAPI2	*Galium pilosum Ait.*	hairy bedstraw	Rubiaceae
GLCA2	*Glandularia canadensis (L.) Nutt.*	rose mock vervain	Verbenaceae
GNOB	*Gnaphalium obtusifolium L.*	fragrant cudweed	Asteraceae

CODE	SPECIES	COMMON NAME	FAMILY
GYBR	*Gymnopogon brevifolius Trin.*	shortleaf skeletongrass	Poaceae
HADI3	*Halesia diptera Ellis*	twowing silverbell	Styracaceae
HEFL	*Helenium flexuosum Raf.*	purplehead sneezeweed	Asteraceae
HEPA19	*Helianthus pauciflorus Nutt.*	stiff sunflower	Asteraceae
HYGA	*Hypericum galioides Lam.*	bedstraw St. Johns-wort	Clusiaceae
ILGL	*Ilex glabra (L.) Gray*	inkberry	Aquifoliaceae
IOLI2	*Ionactis linariifolius (L.) Greene*	ionactis	Asteraceae
ISVE	*Isotria verticillata Raf.*	purple fiveleaf orchid	Orchidaceae
ITVI	*Itea virginica L.*	Virginia sweetspire	Grossulariaceae
JUMA4	*Juncus marginatus Rostk.*	grassleaf rush	Juncaceae
KRCE	*Krigia cespitosa (Raf.) Chambers*	weedy dwarfdandelion	Asteraceae
LECA8	*Lespedeza capitata Michx.*	roundhead lespedeza	Fabaceae
LEST5	*Lespedeza stuevei Nutt.*	tall lespedeza	Fabaceae
LEVI7	*Lespedeza virginica (L.) Britt.*	slender lespedeza	Fabaceae
LIPY	*Liatris pycnostachya Michx.*	cattail gayfeather	Asteraceae
LIMI	*Lilium michauxii Poir.*	Carolina lily	Liliaceae
LIME2	*Linum medium (Planch.) Britt.*	stiff yellow flax	Linaceae
LIRI	*Linum rigidum Pursh*	stiffstem flax	Linaceae
LOSP	*Lobelia spicata Lam.*	palespike lobelia	Campanulaceae
MAUN	*Malaxis unifolia Michx.*	green addersmouth orchid	Orchidaceae
MAGO	*Matelea gonocarpos (Walt.) Shinners*	angularfruit milkvine	Asclepiadaceae
MEMU	*Melica mutica Walt.*	two-flower melic grass	Poaceae
MOFI	*Monarda fistulosa L.*	wildbergamot beebalm	Lamiaceae
OXDI2	*Oxalis dillenii Jacq.*	Dillen's oxalis	Oxalidaceae

CODE	SPECIES	COMMON NAME	FAMILY
OXVI	*Oxalis violacea L.*	violet woodsorrel	Oxalidaceae
PECA	*Pedicularis canadensis L.*	Canadian lousewort	Scrophulariaceae
PHPI	*Phlox pilosa L.*	downy phlox	Polemoniaceae
PHPU8	*Physalis pumila Nutt.*	dwarf groundcherry	Solanaceae
PHDI7	*Physostegia digitalis Small*	finger false dragonhead	Lamiaceae
PLCL	*Platanthera clavellata (Michx.) Luer*	green woodland orchid	Orchidaceae
POLE4	*Polygala leptocaulis Torr. & Gray*	swamp milkwort	Polygalaceae
POMA8	*Polygala mariana P. Mill.*	Maryland milkwort	Polygalaceae
POSI2	*Potentilla simplex Michx.*	common cinquefoil	Rosaceae
PRVU	*Prunella vulgaris L.*	common selfheal	Lamiaceae
PRUM	*Prunus umbellata Ell.*	hog plum	Rosaceae
PYAL	*Pycnanthemum albescens Torr. & Gray*	whiteleaf mountainmint	Lamiaceae
PYCA2	*Pyrrhopappus carolinianus (Walt.) DC.*	Carolina desertchicory	Asteraceae
QULY	*Quercus lyrata Walt.*	overcup oak	Fagaceae
RHCA7	*Rhododendron canescens (Michx.) Sweet*	mountain azalea	Ericaceae
RHDI2	*Rhynchosia difformis (Ell.) DC.*	doubleform snoutbean	Fabaceae
RHLA5	*Rhynchosia latifolia Nutt. ex Torr. & Gray*	prairie snoutbean	Fabaceae
RHGL2	*Rhynchospora globularis (Chapman) Small*	globe beakrush	Cyperaceae
RHGL3	*Rhynchospora glomerata (L.) Vahl*	clustered beaksedge	Cyperaceae
RHGR2	*Rhynchospora grayi Kunth*	Gray's beaksedge	Cyperaceae
RUAR5	*Rubus arvensis Bailey*	field blackberry	Rosaceae
RUPE8	*Rubus persistens Rydb.*	persistent blackberry	Rosaceae
SALY2	*Salvia lyrata L.*	lyreleaf sage	Lamiaceae
SASM	*Sanicula smallii Bickn.*	Small's blacksnakeroot	Apiaceae

CODE	SPECIES	COMMON NAME	FAMILY
SCTE5	*Schizachyrium tenerum Nees*	slender bluestem	Poaceae
SCTR	*Scleria triglomerata Michx.*	whip nutrush	Cyperaceae
SCOV	*Scutellaria ovata Hill*	heartleaf skullcap	Lamiaceae
SCPA7	*Scutellaria parvula Michx.*	small skullcap	Lamiaceae
SETO2	*Senecio tomentosus Michx.*	woolly ragwort	Asteraceae
SIAS2	*Silphium asteriscus L.*	starry rosinweed	Asteraceae
SILPH	*Silphium L.*	rosinweed	Asteraceae
SIRA2	*Silphium radula Nutt.*	roughstem rosinweed	Asteraceae
SMILA2	*Smilax L.*	greenbrier	Smilacaceae
SMWA	*Smilax walteri Pursh*	coral greenbrier	Smilacaceae
SOAU2	*Solidago auriculata Shuttlw. ex Blake*	eared goldenrod	Asteraceae
SOCA4	*Solidago caesia L.*	wreath goldenrod	Asteraceae
SOUL2	*Solidago ulmifolia Muhl. ex Willd.*	elmleaf goldenrod	Asteraceae
SPTU	*Spiranthes tuberosa Raf.*	little ladiestresses	Orchidaceae
STLE6	*Strophostyles leiosperma (Torr. & Gray) Piper*	slickseed fuzzybean	Fabaceae
STHU2	*Stylisma humistrata (Walt.) Chapman*	southern dawnflower	Convolvulaceae
STCA6	*Stylodon carneus (Medik.) Moldenke*	Carolina false vervain	Verbenaceae
TELU	*Tetragonotheca ludoviciana (Torr. & Gray) Gray ex Hall*	Louisiana nerveray	Asteraceae
TICA	*Tilia caroliniana P. Mill.*	Carolina basswood	Tiliaceae
TOVE	*Toxicodendron vernix (L.) Kuntze*	poison sumac	Anacardiaceae
TRRE	*Tradescantia reverchonii Bush*	Reverchon's spiderwort	Commelinaceae
TRWA	*Triadenum walteri (J.G. Gmel.) Gleason*	greater marsh St. Johnswort	Clusiaceae
TRFL2	*Tridens flavus (L.) A.S. Hitchc.*	purpletop tridens	Poaceae
VIOLA	*Viola L.*	violet	Violaceae

CODE	SPECIES	COMMON NAME	FAMILY
VIMI3	*Viola missouriensis Greene*	Missouri violet	Violaceae
VIPE	*Viola pedata L.*	birdfoot violet	Violaceae
VITR2	*Viola triloba Schwein.*	three-lobed violate	Violaceae
VIAEL	*Vitis aestivalis Michx. var. lincecumii (Buckley) Munson*	long grape	Vitaceae
VIMU2	*Vitis mustangensis Buckl.*	mustang grape	Vitaceae

Table 14- Ground species identified in 2016 with codes from the U.S. Department of Agriculture Plant database, common name and family

CODE	SPECIES	COMMON NAME	FAMILY
ANAM2	*Antennaria parlinii Fern.*	pussytoes	Asteraceae
ANVI4	*Anthaenantia villosa (Michx.) Beauv.*	green silkyscale	Poaceae
ARLO	*Aristida longispica Poir.*	red three-awn	Rubiaceae
ARPU8	*Aristida purpurascens Poir.*	arrowfeather threeawn	Poaceae
ARDE3	*Aristida desmantha Trin. & Rupr.*	curly threeawn	Poaceae
ARLA6	*Aristida lanosa Muhl. ex Elliott*	woollysheath threeawn	Poaceae
ASPL	*Asplenium platyneuron (L.) B.S.P.*	ebony spleenwort	Aspleniaceae
BABR2	*Baptisia bracteata Muhl. ex Ell.*	longbract wild indigo	Fabaceae
BOBI	*Botrychium biternatum (Sav.)*	sparse lobed grape fern	Ophioglossaceae
BUBI	*Burmannia biflora L.*	northern bluethread	Burmanniaceae
CALO6	*Carex louisianica Bailey*	Louisiana sedge	Cyperaceae
CAMY	*Carya myristiciformis (Michx. f.) Nutt.*	nutmeg hickory	Juglandaceae
CHLA5	*Chasmanthium latifolium (Michx.) Yates*	indian woodoats	Poaceae
CIRSI	*Cirsium P. Mill.*	thistle	Asteraceae
CLVI	*Clematis virginiana L.*	virgin's bower	Ranunculaceae
CLMA4	*Clitoria mariana L.*	Atlantic pigeonwings	Fabaceae

CODE	SPECIES	COMMON NAME	FAMILY
CRMA5	*Crataegus marshallii Egglest.*	parsley hawthorn	Rosaceae
CRVI2	*Crataegus viridis L.*	green hawthorn	Rosaceae
CRCA6	*Croton capitatus Michx.*	goat weed	Euphorbiaceae
CRGL2	*Croton glandulosus L.*	vente conmigo	Euphorbiaceae
CRMI8	*Croton michauxii G.L. Webster*	Michaux's croton	Euphorbiaceae
CYCR6	*Cyperus croceus Vahl*	Baldwin's flat sedge	Cyperaceae
DELE2	*Desmanthus leptolobus Torr. & A. Gray*	slenderlobe bundleflower	Fabaceae
DELA2	*Desmodium laevigatum (Nutt.) DC.*	smooth ticktrefoil	Fabaceae
DEOB	*Desmodium obtusum (Muhl ex. Willd) DC.*	stiff tretickfoil	Fabaceae
DEVI4	*Desmodium viridiflorum (L.) DC.*	velvetleaf ticktrefoil	Fabaceae
DESMO	*Desmodium Desv.*	ticktrefoil	Fabaceae
DIBO2	*Dichanthelium boscii (Poir.) Gould & C.A. Clark*	Bosc's panicgrass	Poaceae
DILA8	*Dichanthelium latifolium (L.) Gould & C.A. Clark*	broadleaf rosette grass	Poaceae
DILA9	*Dichanthelium laxiflorum (Lam.) Gould*	openflower rosette grass	Poaceae
ELCA3	*Elephantopus carolinianus Raeusch.*	Carolina elephantsfoot	Asteraceae
EREL	*Eragrostis elliottii S. Watson*	field lovegrass	Poaceae
EUSE2	*Eupatorium serotinum Michx.*	lateflowering thoroughwort	Asteraceae
EULE4	*Euthamia leptocephala (Torr. & Gray) Greene*	bushy goldentop	Asteraceae
GAUN2	*Galium uniflorum Michx.*	oneflower bedstraw	Rubiaceae
GATR3	*GaliumÿtriflorumÿMichx.*	fragrant bedstraw	Rubiaceae
HENI4	*Hedyotis nigricans (Lam.) Fosberg*	diamondflowers	Rubiaceae
HEDE4	*Helianthus debilis Nutt.*	cucumberleaf sunflower	Asteraceae

CODE	SPECIES	COMMON NAME	FAMILY
HYOC2	*Hymenocallis occidentalis*	woodland, hammock or northern spider-lily	Amaryllidaceae
HYFR	*Hypericum frondosum Michx.*	cedar glade St. John's-wort	Clusiaceae
ILLO	*Ilex longipes Chapman ex Trel.*	Georgia holly	Aquifoliaceae
IPCO8	*Ipomoea cordatotriloba Dennst.*	tievine	Convolvulaceae
LAFL	*Lactuca floridana (L.) Gaertn.*	woodland lettuce	Asteraceae
LEVI2	*Leersia virginica Willd.*	whitegrass	Poaceae
LEVI3	*Lepidium virginicum L.*	poorman's pepperwort	Brassicaceae
LIEL	*Liatris elegans (Walter) Michx.*	pinkscale blazing star	Asteraceae
LISQ	*Liatris squarrosa (L.) Michx.*	scaly gayfeather	Asteraceae
LISI	*Ligustrum sinense Lour.*	Chinese privet	Oleaceae
LOPU	*Lobelia puberula Michx.*	downy lobelia	Campanulaceae
LOJA	*Lonicera japonica Thunb.*	Japanese honeysuckle	Caprifoliaceae
LUAL2	*Ludwigia alternifolia L.*	seedbox	Onagraceae
LYJA	*Lygodium japonicum (Thunb.) Sw.*	Japanese climbing fern	Lygodiaceae
MAVI2	*Magnolia virginiana L.*	sweetbay	Magnoliaceae
MADE3	*Matelea decipiens (Alexander) Woods.*	oldfield milkvine	Asclepiadaceae
MOPU	*Monarda punctata L.*	spotted beebalm	Lamiaceae
MUCA2	*Muhlenbergia capillaris (Lam.) Trin.*	hairawn muhly	Poaceae
ONSE	*Onoclea sensibilis L.*	sensitive fern	Dryopteridaceae
OPHU	*Opuntia humifusa (Raf.) Raf.*	Devil's-tongue	Cactaceae
PAAN	*Panicum anceps Michx.*	beaked panicum	Poaceae
PABR2	*Panicum brachyanthum Steud.*	prairie panicgrass	Poaceae
PADI	*Panicum dichotomiflorum Michx.*	fall panicgrass	Poaceae

CODE	SPECIES	COMMON NAME	FAMILY
PAVE2	*Panicum verrucosum Muhl.*	warty panicgrass	Poaceae
PAFL4	*Paspalum floridanum Michx.*	Florida paspalum	Poaceae
PASE5	*Paspalum setaceum Michx.*	thin paspalum	Poaceae
PAUR2	*Paspalum urvillei Steud.*	Vasey's grass	Poaceae
PABI3	*Paspalum bifidum (Bertol.) Nash*	pitchfork crowngrass	Poaceae
PELA10	*Penstemon laxiflorus Pennell*	nodding beardtongue	Scrophulariaceae
PLCI2	*Plantanthera ciliaris (L.) Lindl.*	yellow-fringed orchid	Orchidaceae
POAU	*Poa autumnalis Muhl. ex Ell.*	autumn bluegrass	Poaceae
PTCA	*Ptilimnium capillaceum (Michx.) Raf.*	herbwilliam	Apiaceae
RHGL	*Rhus glabra L.*	smooth sumac	Fabaceae
RHMI4	*Rhynchosia minima (L.) DC.*	least snoutbean	Fabaceae
RHRE8	*Rhynchospora recognita (Gale) Kral*	globe beaksedge	Cyperaceae
RUAB	*Rubus aboriginum Rydb.*	garden dewberry	Rosaceae
RUTR	*Rubus trivialis Michx.*	southern dewberry	Rosaceae
SAAR	*Sabatia arenicola Greenm.*	sand rose gentian	Gentianaceae
SCPA5	*Scleria pauciflora Muhl. ex Willd.*	fewflower nutrush	Cyperaceae
SONE	*Solidago nemoralis Aiton*	gray goldenrod	Asteraceae
SONI2	*Solidago nitida Torr. & Gray*	shiny goldenrod	Asteraceae
SORU2	*Solidago rugosa P. Mill.*	wrinkleleaf goldenrod	Asteraceae
SOEL3	*Sorghastrum elliottii (C. Mohr) Nash*	slender Indiangrass	Poaceae
SONU2	*Sorghastrum nutans (L.) Nash*	indian woodoats	Poaceae
SPOV	*Spiranthes ovalis Lindl.*	October ladiestresses	Orchidaceae

CODE	SPECIES	COMMON NAME	FAMILY
SPJU	*Sporobolus junceus (Beauv.) Kunth*	Pineywoods dropseed	Poaceae
STGR2	*Stenanthium gramineum (Ker-Gawl.) Morong*	eastern featherbells	Liliaceae
STNIF	*Stenaria nigricans (Lam.) Terrell*	diamond-flowers; fineleaf bluets	Rubiaceae
SYPA11	*Symphyotrichum patens (Aiton) G.L. Nesom*	late purple aster	Asteraceae
THFL	*Thelesperma flavodiscum (Shinners) B.L. Turner*	east Texas greenthread	Asteraceae
TOPU2	*Toxicodendron pubescens P. Mill.*	Atlantic poison oak	Anacardiaceae
VACO	*Vaccinium corymbosum L.*	highbush blueberry	Ericaceae
VIDE	*Viburnum dentatum L.*	southern arrowwood	Caprifoliaceae
VITE	*Vicia tetrasperma (L.) Schreb.*	lentil vetch	Fabaceae
VISO	*Viola sororia Willd.*	common blue violet	Violaceae
VICI2	*Vitis cinerea (Engelm.) Millard*	gray-bark grape	Vitaceae
WOVI	*Woodwardia virginica (L.) Sm.*	Virginia chainfern	Blechnaceae
ZAAM	*Zanthoxylum americanum Mill.*	common pricklyash	Rutaceae

Table 15 - Midstory species identified in 1994/95 and 2016 with codes from the U.S. Department of Agriculture Plant database, common name and family

CODE	SPECIES	COMMON NAME	FAMILY
ACBA3	Acer barbatum Michx.	Florida maple	Aceraceae
ACRU	*Acer rubrum L.*	red maple	Aceraceae
ASPA18	*Asimina parviflora (Michx.) Dunal*	smallflower pawpaw	Annonaceae
ASTR	*Asimina triloba (L.) Dunal*	common pawpaw	Annonaceae
CAAM2	*Callicarpa americana L.*	American beautyberry	Verbenaceae
CACA18	*Carpinus caroliniana Walt.*	American hornbeam	Betulaceae
CAAL27	*Carya alba (L.) Nutt. ex Ell.*	mockernut hickory	Juglandaceae
CACO15	*Carya cordiformis (Wangenh.) K. Koch*	bitternut hickory	Juglandaceae
CATE9	*Carya texana Buckl.*	black hickory	Juglandaceae
CAPU9	*Castanea pumila (L.) P. Mill.*	Allegheny chinkapin	Fagaceae
CELA	*Celtis laevigata Willd.*	sugarberry	Ulmaceae
CHVI3	*Chionanthus virginicus L.*	white fringetree	Oleaceae
COFL2	*Cornus florida L.*	flowering dogwood	Cornaceae
CRBR	*Crataegus brachyacantha Sarg. & Engelm.*	blueberry hawthorn	Rosaceae
CRMA5	*Crataegus marshallii Egglest.*	parsley hawthorn	Rosaceae
FAGR	*Fagus grandifolia Ehrh.*	American beech	Fagaceae
FOLI	*Forestiera ligustrina (Michx.) Poir.*	upland swampprivet	Oleaceae
FRCA13	*Frangula caroliniana (Walt.) Gray*	Carolina buckthorn	Rhamnaceae
FRAM2	*Fraxinus americana L.*	white ash	Oleaceae
FRPE	*Fraxinus pennsylvanica Marsh.*	green ash	Oleaceae
HAVI4	*Hamamelis virginiana L.*	American witchhazel	Hamamelidaceae
ILCO	*Ilex coriacea (Pursh) Chapman*	large gallberry	Aquifoliaceae
ILOP	*Ilex opaca Ait.*	American holly	Aquifoliaceae
ILVO	*Ilex vomitoria Ait.*	yaupon	Aquifoliaceae

CODE	SPECIES	COMMON NAME	FAMILY
JUVI	*Juniperus virginiana L.*	eastern redcedar	Cupressaceae
LIST2	*Liquidambar styraciflua L.*	sweetgum	Hamamelidaceae
MAGR4	*Magnolia grandiflora L.*	southern magnolia	Magnoliaceae
MAVI2	*Magnolia virginiana L.*	sweetbay	Magnoliaceae
MYHE	*Morella caroliniensis (P.Mill.) Small*	evergreen bayberry	Myricaceae
MYCE	*Morella cerifera (L.) Small*	southern bayberry	Myricaceae
NYSY	*Nyssa sylvatica Marsh.*	blackgum	Nyssaceae
OSVI	*Ostrya virginiana (P. Mill.) K. Koch*	eastern hophornbeam	Betulaceae
PEBO	*Persea borbonia (L.) Spreng.*	redbay	Lauraceae
PIEC2	*Pinus echinata P. Mill.*	shortleaf pine	Pinaceae
PIPA2	*Pinus palustris P. Mill.*	longleaf pine	Pinaceae
PITA	*Pinus taeda L.*	loblolly pine	Pinaceae
QUAL	*Quercus alba L.*	white oak	Fagaceae
QUFA	*Quercus falcata Michx.*	southern red oak	Fagaceae
QUIN	*Quercus incana Bartr.*	bluejack oak	Fagaceae
QUMA6	*Quercus margarettiae Ashe ex Small*	runner oak	Fagaceae
QUMA3	*Quercus marilandica Muenchh.*	blackjack oak	Fagaceae
QUNI	*Quercus nigra L.*	water oak	Fagaceae
QUPH	*Quercus phellos L.*	willow oak	Fagaceae
RHCO	*Rhus copallinum L.*	flameleaf sumac	Anacardiaceae
RHCA7	*Rhododendron canescens (Michx.) Sweet*	mountain azalea	Ericaceae
SAAL5	*Sassafras albidum (Nutt.) Nees*	sassafras	Lauraceae
SYTI	*Symplocos tinctoria (L.) L'Her.*	common sweetleaf	Symplocaceae
TIAM	*Tilia americana L.*	American basswood	Tiliaceae
ULAL	*Ulmus alata Michx.*	winged elm	Ulmaceae
VAAR	*Vaccinium arboreum Marsh.*	farkleberry	Ericaceae
VAEL	*Vaccinium elliottii Chapman*	Elliott's blueberry	Ericaceae

CODE	SPECIES	COMMON NAME	FAMILY
VACO	*Vaccinium corymbosum L.*	highbush blueberry	Ericaceae
VAST	*Vaccinium stamineum L.*	deerberry	Ericaceae
VINU	*Viburnum nudum L.*	possumhaw	Caprifoliaceae
VIRO3	*Vitis rotundifolia Michx.*	muscadine	Vitaceae
VIRU	*Viburnum rufidulum Raf.*	rusty blackhaw	Caprifoliaceae

Table 16 - Midstory species identified in 1994/95 with codes from the U.S. Department of Agriculture Plant database, common name and family

CODE	SPECIES	COMMON NAME	FAMILY
BESC	*Berchemia scandens (Hill) K. Koch*	Alabama supplejack	Rhamnaceae
CECA4	*Cercis canadensis L.*	eastern redbud	Fabaceae
CRSP	*Crataegus spathulata Michx.*	littlehip hawthorn	Rosaceae
DIVI5	*Diospyros virginiana L.*	common persimmon	Ebenaceae
PRSE2	*Prunus serotina Ehrh.*	black cherry	Rosaceae
TOVE	*Toxicodendron vernix (L.) Kuntze*	poison sumac	Anacardiaceae

Table 17 - Midstory species identified in 2016 with codes from the U.S. Department of Agriculture Plant database, common name and family

CODE	SPECIES	COMMON NAME	FAMILY
ARAR7	*Aronia arbutifolia (L.) Pers.*	red chokeberry	Rosaceae
CAMY	*Carya myristiciformis (Michx. f.) Nutt.*	nutmeg hickory	Juglandaceae
CAOV2	*Carya ovata (P. Mill.) K. Koch*	shagbark hickory	Juglandaceae
ILDE	*Ilex decidua Walt.*	possumhaw	Aquifoliaceae
LEVI2	*Leersia Sw.*	cutgrass	Poaceae
MORU2	*Morus rubra L.*	red mulberry	Moraceae
PRCA	*Prunus caroliniana (P. Mill.) Ait.*	Carolina laurelcherry	Rosaceae
QULA3	*Quercus laurifolia Michx.*	laurel oak	Fagaceae
RHAR4	*Rhus aromatica Ait.*	fragrant sumac	Anacardiaceae
RHGL	*Rhus glabra L.*	smooth sumac	Fabaceae
RUAR2	*Rubus argutus Link*	sawtooth blackberry	Rosaceae
SEFR	*Sebastiania fruticosa (Bartr.) Fern.*	gulf sebastiana	Euphorbiaceae
VIAC	*Viburnum acerifolium L.*	mapleleaf viburnum	Caprifoliaceae

Table 18 - Overstory species identified in 1994/95 and 2016 with codes from the U.S. Department of Agriculture Plant database, common name and family

CODE	SPECIES	COMMON NAME	FAMILY
ACBA3	*Acer barbatum Michx.*	Florida maple	Aceraceae
ACRU	*Acer rubrum L.*	red maple	Aceraceae
CACA18	*Carpinus caroliniana Walt.*	American hornbeam	Betulaceae
CAAL27	*Carya alba (L.) Nutt. ex Ell.*	mockernut hickory	Juglandaceae
CACO15	*Carya cordiformis (Wangenh.) K. Koch*	bitternut hickory	Juglandaceae
CATE9	*Carya texana Buckl.*	black hickory	Juglandaceae
COFL2	*Cornus florida L.*	flowering dogwood	Cornaceae
FAGR	*Fagus grandifolia Ehrh.*	American beech	Fagaceae
FRAM2	*Fraxinus americana L.*	white ash	Oleaceae
ILOP	*Ilex opaca Ait.*	American holly	Aquifoliaceae
LIST2	*Liquidambar styraciflua L.*	sweetgum	Hamamelidaceae
MAGR4	*Magnolia grandiflora L.*	southern magnolia	Magnoliaceae
MAVI2	*Magnolia virginiana L.*	sweetbay	Magnoliaceae
NYSY	*Nyssa sylvatica Marsh.*	blackgum	Nyssaceae
OSVI	*Ostrya virginiana (P. Mill.) K. Koch*	eastern hophornbeam	Betulaceae
PEBO	*Persea borbonia (L.) Spreng.*	redbay	Lauraceae
PIEC2	*Pinus echinata P. Mill.*	shortleaf pine	Pinaceae
PIPA2	*Pinus palustris P. Mill.*	longleaf pine	Pinaceae
PITA	*Pinus taeda L.*	loblolly pine	Pinaceae
PRSE2	*Prunus serotina Ehrh.*	black cherry	Rosaceae
QUAL	*Quercus alba L.*	white oak	Fagaceae
QUFA	*Quercus falcata Michx.*	southern red oak	Fagaceae
QUIN	*Quercus incana Bartr.*	bluejack oak	Fagaceae
QULA3	*Quercus laurifolia Michx.*	laurel oak	Fagaceae
QUNI	*Quercus nigra L.*	water oak	Fagaceae
QUST	*Quercus stellata Wangenh.*	post oak	Fagaceae
SILA20	*Sideroxylon lanuginosum Michx.*	gum bully (Chittimwood)	Sapotaceae
ULAL	*Ulmus alata Michx.*	winged elm	Ulmaceae

Table 19 - Overstory species identified in 1994/95 with codes from the U.S. Department of Agriculture Plant database, common name and family.

CODE	SPECIES	COMMON NAME	FAMILY
CECA4	*Cercis canadensis L.*	eastern redbud	Fabaceae
PIEL	*Pinus elliottii Engelm.*	slash pine	Pinaceae
SAAL5	*Sassafras albidum (Nutt.) Nees*	sassafras	Lauraceae
TIAM	*Tilia americana L.*	American basswood	Tiliaceae

Table 20 - Overstory species identified in 2016 with codes from the U.S. Department of Agriculture Plant database, common name and family

CODE	SPECIES	COMMON NAME	FAMILY
CHVI3	*Chionanthus virginicus L.*	white fringetree	Oleaceae
ILCO	*Ilex coriacea (Pursh) Chapman*	large gallberry	Aquifoliaceae
JUVI	*Juniperus virginiana L.*	eastern redcedar	Cupressaceae
QUPH	*Quercus phellos L.*	willow oak	Fagaceae
ULAM	*Ulmus americana L.*	American elm	Ulmaceae

Table 21 - Shannon Diversity Index of the 30 upland forest stands from the Angelina and Sabine National Forests, Texas, USA, sampled in 1994/95 and resampled in 2016. No significant difference in overstory diversity was indicated in the stand overstory stratum (P = 0.070). Midstory diversity was indicated to be significant for the Longleaf pine upland (ecosystem 1), indicated in bold (P = 0.0434) and the Dry-mesic uplands (ecosystem 2), indicated in bold (P = 0.0029). The herbaceous layer was indicated as having a significant difference in diversity for the Dry-mesic uplands (ecosystem 2), indicated in bold (P = 0.0002) and in the Mesic slopes ecosystem (ecosystem 3) indicated in bold (P = 0.0058).

SHANNON INDEX (H')							
		Overstory		**Midstory**		**Herbaceous**	
Ecosystem	**Stand**	**1994/95**	**2016**	**1994/95**	**2016**	**1994/95**	**2016**
1	A92B	0	0	0.978455	**0.878216**	3.711739	3.641183
	A92C	0.756173	0.587437	1.706679	**0.971722**	4.017383	3.090304
	A98C	0	0.26279	2.150613	**1.606154**	3.89403	3.460047
	A98F	0.667215	0	1.82553	**1.231546**	4.032171	3.484692
	A98G	1.082317	1.076666	1.725463	**1.536714**	3.88235	3.419499
2	A0624	1.21222	0.955158	2.469827	**1.621968**	3.86349	**3.279540**
	A1113	1.270024	1.590001	1.632076	**1.630885**	4.011907	**3.151174**
	A1122	1.657287	1.715061	1.762001	**1.660187**	3.759873	**3.544166**
	A1128	2.094998	2.022164	2.66197	**1.864171**	4.109954	**3.513918**
	A2610	1.493787	1.495714	2.421489	**1.564728**	3.841126	**3.371077**
	A2801C	2.184361	2.056823	2.086738	**0.798477**	3.851751	**3.323872**
	A2801D	1.951704	1.911978	2.029596	**0.718497**	3.506437	**3.134014**
	A1407	1.561956	1.729187	2.210723	**1.308505**	4.02004	**3.684793**
3	A2801A	2.222773	2.153685	2.61724	2.052399	4.006781	**3.372510**
	A0130	1.885061	1.770273	1.310336	0.634179	3.368284	**3.460231**
	A2025A	2.34915	2.185362	2.161905	3.159422	3.828918	**3.865152**
	A2010A	2.126138	1.814423	1.819656	1.652464	3.481287	**2.794574**
	A2010B	2.06153	2.00778	2.060733	1.83403	3.132802	**2.951110**
	S6797A	1.77584	1.932371	2.139345	1.720475	3.65478	**3.277285**
	S6797B	1.881621	1.850184	2.367511	1.86069	3.936189	**3.364878**
	S6797C	2.233457	2.190516	2.115612	2.258688	3.793796	**2.983955**
	S6797D	1.831544	1.8464	1.491728	1.385465	3.597532	**2.703358**
4	S5113	0.659279	0	0.809382	0.875118	3.249507	3.454209
	S5201A	1.565128	1.220924	2.121718	2.214823	3.737747	3.440171
	S5201B	1.836003	1.786867	1.783657	1.576144	3.693073	3.433597
	S5297A	1.209978	1.187767	1.890558	1.383247	3.157372	3.241306
	S5297B	1.487335	1.26999	1.233863	1.705034	3.65479	3.151729
5	A1490	2.07445	1.9242	2.401658	1.803325	3.672588	3.343506
	A1612	1.66153	1.956569	1.968621	2.275468	3.516109	3.361078
	A76A	2.262494	2.230054	2.487908	1.473145	3.61838	3.113286

Table 22 - Pielou's Evenness Index of the 30 upland forest stands from the Angelina and Sabine National Forests, Texas, USA, sampled in 1994/95 and resampled in 2016. No significant difference in overstory evenness was indicated in the stand overstory stratum (P = 0.4577). Midstory eveness was indicated to be significant for the Dry-mesic uplands (ecosystem 2), indicated in bold (P = 0.0003) and in the herbaceous layer for the Longleaf pine uplands (ecosystem 1), indicated in bold (P = 0.0143). NaN values indicate values too low to establish evenness calculations.

PIELOUS's EVENNESS (J)							
		Overstory		**Midstory**		**Herbaceous**	
Ecosystem		**1994/95**	**2016**	**1994/95**	**2016**	**1994/95**	**2016**
1	A92B	NaN	NaN	0.890628	0.799387	0.892485	**0.900603**
	A92C	0.688298	0.847493	0.952516	0.884499	0.914195	**0.862366**
	A98C	NaN	0.379125	0.933999	0.896412	0.926115	**0.908945**
	A98F	0.607325	NaN	0.830835	0.888373	0.925509	**0.886278**
	A98G	0.985168	0.77665	0.829772	0.857656	0.940689	**0.898293**
2	A0624	0.676553	0.689001	0.871741	**0.676413**	0.89211	0.895178
	A1113	0.708814	0.887397	0.910879	**0.838109**	0.905455	0.893605
	A1122	0.796987	0.881367	0.847343	**0.798381**	0.897418	0.915521
	A1128	0.873682	0.878215	0.939559	**0.848421**	0.913362	0.885053
	A2610	0.833699	0.719287	0.894182	**0.804111**	0.910326	0.896277
	A2801C	0.948656	0.9361	0.839765	**0.726805**	0.919348	0.907279
	A2801D	0.888259	0.870179	0.791281	**0.654004**	0.85641	0.874563
	A1407	0.802687	0.888626	0.837694	**0.672439**	0.917393	0.896353
3	A2801A	0.926968	0.935334	0.94397	0.934087	0.916999	0.920555
	A0130	0.818672	0.909741	0.945207	0.914926	0.895534	0.903775
	A2025A	0.915866	0.911367	0.901584	0.911617	0.92416	0.929373
	A2010A	0.886668	0.872553	0.875069	0.922258	0.919956	0.879335
	A2010B	0.859725	0.837309	0.894965	0.834703	0.874225	0.867668
	S6797A	0.853998	0.87946	0.929106	0.747193	0.916218	0.907605
	S6797B	0.817178	0.803525	0.835628	0.956206	0.917428	0.860138
	S6797C	0.846309	0.913516	0.851385	0.855869	0.908827	0.839286
	S6797D	0.833572	0.840333	0.766596	0.773243	0.914978	0.839846
4	S5113	0.600102	NaN	0.583846	0.796566	0.88698	0.882973
	S5201A	0.804317	0.758603	0.884825	0.923653	0.902154	0.893517
	S5201B	0.882931	0.859302	0.774633	0.757965	0.925818	0.907353
	S5297A	0.872815	0.856793	0.860430	0.772005	0.867986	0.872827
	S5297B	0.924133	0.789089	0.890044	0.819948	0.882132	0.879507
5	A1490	0.865113	0.875741	0.936337	0.867216	0.900688	0.888947
	A1612	0.927318	0.890473	0.792232	0.862227	0.903461	0.893619
	A76A	0.943533	0.930005	0.878122	0.670457	0.924938	0.898305

Table 23 - Overstory species richness and turnover for the 30 upland forest stands from the Angelina and Sabine National Forests, Texas, USA, sampled in 1994/95 and resampled in 2016. Paired t-tests indicate no significant difference in overstory species richness (P = 0.2090). Analysis of variance tests indicate no significant difference in turnover rates (TA) and relative turnover rates (TR) in the overstory (P = 0.095 and P = 0.712, respectively).

Overstory								
		Species richness			Turnover			
Ecosystem	**Stand**	S_{2016}	$S_{1994/95}$	S_{pool}	I	E	TA	TR
1	A92B	1	1	1	0	0	0	0
	A92C	2	3	2	0	1	0.024	0.952
	A98C	2	1	1	1	0	0.024	1.587
	A98F	1	3	1	0	2	0.048	2.381
	A98G	4	3	3	1	0	0.024	0.680
2	A0624	4	6	4	0	2	0.045	0.909
	A1113	6	6	4	2	2	0.091	1.515
	A1122	7	8	6	1	2	0.068	0.909
	A1128	10	11	9	1	2	0.068	0.649
	A2610	8	6	5	3	1	0.091	1.299
	A2801C	9	10	9	0	1	0.023	0.239
	A2801D	9	9	7	2	2	0.091	1.010
	A1407	7	7	6	1	1	0.045	0.649
3	A2801A	10	11	8	2	3	0.114	1.082
	A0130	7	10	6	1	4	0.114	1.623
	A2025A	11	13	8	3	5	0.182	1.515
	A2010A	8	11	7	1	4	0.114	1.196
	A2010B	11	11	9	2	2	0.091	0.826
	S6797A	9	8	7	2	1	0.071	0.840
	S6797B	10	10	9	1	1	0.048	0.476
	S6797C	11	14	11	0	3	0.071	0.571
	S6797D	9	9	8	1	1	0.048	0.529
4	S5113	1	3	1	0	2	0.048	2.381
	S5201A	5	7	4	1	3	0.095	1.587
	S5201B	8	8	7	1	1	0.048	0.595
	S5297A	4	4	4	0	0	0.000	0.000
	S5297B	5	5	3	2	2	0.095	1.905
5	A1490	9	11	7	2	4	0.136	1.364
	A1612	9	6	6	3	0	0.068	0.909
	A76A	11	11	9	2	2	0.095	0.866

Table 24 – Midstory species richness and turnover rates for the 30 upland forest stands from the Angelina and Sabine National Forests, Texas, USA, sampled in 1994/95 and resampled in 2016. Paired t-tests indicate significant differences in midstory species richness in the Longleaf pine ecosystem (ecosystem 1), indicated in bold (P = 0.0221), the Dry-mesic ecosystem (ecosystem 2), indicated in bold (P = 0.0050). Analysis of variance tests indicate no significant difference in turnover rates (TA) and relative turnover rates (TR) in the overstory (P = 0.10801 and P = 0.6774, respectively).

Midstory								
		Species richness			**Turnover**			
Ecosystem	**Stand**	**S_{2016}**	**$S_{1994/95}$**	**S_{pool}**	**I**	**E**	**TA**	**TR**
1	A92B	**3**	3	1	2	2	0.095	3.175
	A92C	**3**	6	2	1	4	0.119	2.646
	A98C	**6**	10	5	1	5	0.143	1.786
	A98F	**4**	9	4	0	5	0.119	1.832
	A98G	**6**	8	6	0	2	0.048	0.680
2	A0624	**11**	17	6	5	10	0.341	2.525
	A1113	**7**	6	2	5	5	0.227	3.247
	A1122	**8**	8	4	4	4	0.182	2.273
	A1128	**9**	17	7	2	10	0.273	2.098
	A2610	**7**	15	7	0	8	0.182	1.653
	A2801C	**3**	12	2	1	10	0.250	3.333
	A2801D	**3**	13	2	1	10	0.250	3.571
	A1407	**7**	14	7	0	7	0.159	1.515
3	A2801A	9	16	5	4	11	0.341	2.727
	A0130	2	4	2	0	2	0.045	1.515
	A2025A	32	11	11	21	0	0.477	2.220
	A2010A	6	8	6	1	3	0.091	1.299
	A2010B	9	10	6	3	4	0.159	1.675
	S6797A	10	10	4	5	7	0.286	2.721
	S6797B	7	17	5	1	12	0.310	2.692
	S6797C	14	12	7	7	5	0.286	2.198
	S6797D	6	7	5	1	2	0.071	1.099
4	S5113	3	4	3	0	1	0.024	0.680
	S5201A	11	11	6	5	5	0.238	5.952
	S5201B	8	10	4	4	6	0.238	2.646
	S5297A	6	9	4	2	5	0.167	2.222
	S5297B	8	4	3	5	0	0.119	2.165
5	A1490	8	13	6	2	7	0.205	1.948
	A1612	14	12	5	7	5	0.273	2.098
	A76A	9	17	7	2	10	0.286	3.571

Table 25 – Herbaceous layer species richness and turnover rates for the 30 upland forest stands from the Angelina and Sabine National Forests, Texas, USA, sampled in 1994/95 and resampled in 2016. Paired t-tests indicate significant differences in herbaceous layer species richness in the Dry-mesic ecosystem (ecosystem 2), indicated in bold (P = 0.0001) and the Mesic slope and stream bottom ecosystem (ecosystem 3), indicated in bold (P = 0.0065). Analysis of variance tests indicate a significant difference in turnover rates (TA) and relative turnover rates (TR) in the herbaceous layers between ecosystems (P = 0.001 and P = 0.004, respectively), indicated in bold.

Herbaceous								
		Species richness			**Turnover**			
Ecosystem	**Stand**	**S_{2016}**	**$S_{1994/95}$**	**S_{pool}**	**I**	**E**	**TA**	**TR**
1	A92B	57	64	31	27	34	**1.452**	**2.362**
	A98C	36	81	26	11	55	**1.571**	**2.663**
	A98C	45	67	29	16	39	**1.310**	**2.318**
	A98F	51	78	19	22	49	**1.690**	**3.102**
	A98G	45	62	25	20	37	**1.357**	**2.537**
2	A0624	**39**	76	29	11	47	**1.318**	**2.273**
	A1113	**34**	84	24	10	59	**1.568**	**2.658**
	A1122	**48**	66	25	22	41	**1.432**	**2.534**
	A1128	**53**	90	32	21	58	**1.795**	**2.511**
	A2610	**43**	68	29	15	40	**1.250**	**2.212**
	A2801C	**39**	66	27	12	39	**1.159**	**2.208**
	A2801D	**36**	60	20	16	40	**1.273**	**2.652**
	A1407	**61**	80	33	28	47	**1.705**	**2.418**
3	A2801A	**39**	79	29	10	50	**1.364**	**2.311**
	A0130	**46**	43	29	17	14	**0.705**	**1.583**
	A2025A	**64**	63	42	22	21	**0.977**	**1.539**
	A2010A	**24**	44	20	4	24	**0.636**	**1.872**
	A2010B	**30**	36	22	8	14	**0.500**	**1.515**
	S6797A	**37**	54	26	11	29	**0.952**	**2.070**
	S6797B	**50**	73	29	21	44	**1.548**	**2.516**
	S6797C	**35**	65	15	10	40	**1.190**	**2.381**
	S6797D	**25**	51	18	7	33	**0.952**	**2.506**
4	S5113	50	39	20	30	19	**1.167**	**2.622**
	S5201A	47	63	29	18	34	**1.238**	**2.251**
	S5201B	44	54	25	19	29	**1.143**	**2.332**
	S5297A	41	38	18	23	20	**1.024**	**2.592**
	S5297B	36	63	25	11	38	**1.167**	**2.357**
5	A1490	43	59	30	13	30	**0.977**	**1.898**
	A1612	43	49	30	13	20	**0.750**	**1.613**
	A76A	32	50	23	9	27	**0.857**	**2.091**

CHAPTER 9 - VITA

VITA

Trisha L. Williams completed her Bachelor of Science degree at Carleton University in Ottawa, Canada. She entered Stephen F. Austin State University at Nacogdoches, Texas in the Fall of 2015 and worked as a Graduate Assistant while completing her degree. She received the degree of Master of Science from Stephen F. Austin State University in May of 2017.

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